TECHNICAL
REPORT

Quaker Valley Digital School District

Early Effects and Plans for Future Evaluation

KERRI A. KERR, JOHN F. PANE,
HEATHER BARNEY

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1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
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PREFACE

This research was conducted for the Quaker Valley School District, located in Sewickley, Pennsylvania, to serve as one piece of a larger, ongoing evaluation of the Quaker Valley Digital School District initiative. The Digital School District program is an educational technology initiative supported by the Pennsylvania Department of Education. Quaker Valley was one of three Pennsylvania districts awarded funds to become a Digital School District in 2001.

As part of its proposal to secure funding for the initiative, Quaker Valley promised summative and formative evaluations of the initiative using quantitative and qualitative research methodologies. To meet the conditions of its award, Quaker Valley contacted the RAND Corporation in October 2002 to request a summative evaluation of program implementation as of the end of Year 2, to supplement the formative evaluation conducted by researchers at Carnegie Mellon University. In addition, Quaker Valley requested that RAND provide a conceptual framework and research design for a long-term, comprehensive evaluation of the Digital School District initiative to be carried out in future years with support from various funding sources.

RAND agreed to conduct a limited implementation study in spring 2003, and to provide a plan for a future, comprehensive evaluation. This report describes the findings of our preliminary evaluation of the program and plans for future study of the initiative.

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BACKGROUND AND PURPOSE

The Quaker Valley School District is one of three districts selected by the Pennsylvania Department of Education to receive a two-year "Digital School District" grant beginning in 2001. Key technology provisions in Quaker Valley's proposal were to supply laptop computers to every student in grades 3–12, to set up wireless networks in all district buildings and several community sites, and to provide wireless Internet connections in the homes of all students in grades 3–12.

The purpose of this report is twofold. First, we provide a limited evaluation of the implementation and impacts of the Digital School District (DSD) program at the end of the grant period, based on data previously collected by the district and its formative evaluator as well as limited qualitative data collection by RAND during a 3-day site visit. Second, we provide a conceptual framework and Theory of Change describing the Quaker Valley program, and a research design for a future, more comprehensive evaluation of the initiative.

FINDINGS

Reports from teachers and students, as well as classroom observations, revealed wide variation in the use of technology across classrooms, both because the technology is more applicable in some subject areas than in others, and also due to variances among teachers' comfort and aptitude with the technology. Overall, teachers and students reported competency in several basic software applications after the first year of the grant, and additional competencies after the second year. The laptops engendered some changes in the classroom by acting as a tool for performing functions that were previously done by hand, such as recording attendance and grades, taking notes, and conducting research. However, teachers reported several factors that seemed to hinder the integration of technology into the curriculum. In particular, they expressed the need for additional professional development and technical support to facilitate curricular integration.

Contrary to an expectation that teachers would have more free time for instruction, teachers reported increased clerical and management demands on their time since the implementation of the DSD program. In addition, teachers who put efforts into developing lessons to utilize the technology found this required a large time commitment, with little formal support from the district. Furthermore, because some students would inevitably come to class without computers, many teachers were required to plan alternate activities that could be performed without the computer, adding to teacher workloads. One promising finding was that teachers were taking advantage of a newly implemented online assessment tool that allows them to design and administer customized assessments and track student progress. These assessments provide teachers with rapid feedback on the progress of the class and individual students, enabling teachers to adapt instruction based on these results.

Wide variation was also seen in use of the home Internet connections provided by the district. In general, these connections suffered many technical problems, and difficulties with safeguards made these connections subject to inappropriate use. Overall, the connections were heavily used by only a handful of students and fewer parents. In addition, there were great problems with reliability of the student laptops, particularly at the middle school level. Technical support staff were overwhelmed with support and repair issues, thus shifting the support burden onto teachers and the technology experts who were supposed to be assisting teachers with curriculum and instruction.

Though use of technology varied widely across the district, positive and negative impacts of the technology initiative were seen for many members of the district. Most prominently, students at all grade levels benefited from increased awareness and competence with technology. Motivation and engagement increases were reported for many students, and teachers reported that students had increased confidence, more willingness to work with and teach other students, and improved communication skills. Some students were reported to take more responsibility for their own learning. However, some negative consequences for students were also observed, such as inappropriate use, and for some students, social difficulties due to excessive use of the computers. Positive impacts for teachers included the availability of new materials and activities for lessons, and increased capacity for communication with students, parents, peers, and principals. However, teachers also reported an increase in workload related to using the technology for both administrative and instructional purposes.

PLANNING FUTURE EVALUATION EFFORTS

To provide guidance in planning a future, more comprehensive evaluation of the initiative, we presented a Theory of Change that integrated key aspects of program implementation as discussed in previous research. Based on this hypothesized description of the theory of action underlying the DSD initiative, we developed a set of research questions to guide future evaluation efforts, including a listing of measures to be considered in future data collection to systematically investigate the various causal pathways and outcomes described in the Theory of Change diagram.

We then described various simple analyses that can be performed with this data, such as analyzing achievement trends over time, and discussed the challenge of interpreting and attributing effects that is inherent to program evaluation studies. Three methods were described for designing a comparison group study that would allow strong conclusions about causality to be made. Unfortunately, none of these methods may be practical options for Quaker Valley due to cost or other limitations inherent to the DSD initiative in Quaker Valley, such as lack of necessary baseline data, no identified comparison group or district, consistently high student achievement, and small district size. As a result of these limitations, an evaluation providing high confidence estimates of the impact of the DSD initiative may not be possible.

RECOMMENDATIONS

Though the district may be unable to make reliable conclusions that directly link the DSD initiative to observed effects, much can be learned from a systematic evaluation of the implementation of the DSD program. Based on findings from qualitative analyses, we offer the following recommendations pertaining to program implementation as of the end of the second year of implementation. The district may want to consider these recommendations when planning for the implementation of the initiative in future years:

- Focus professional development on curricular integration of technology.
- Provide an accountability mechanism that clearly states the district's expectations for how the technology will be used in instruction and provides incentives for compliance and consequences for non-compliance with these expectations.

- Increase the level of support staffing, for technical support, troubleshooting, and repair issues as well as for curricular support to assist teachers with integration of technology into their lessons and instruction.
- Reconsider the current policy of uniformly issuing personal laptops to all students across grades 3–12.
- Set up formal mechanisms for all stakeholders to provide input to program administrators, establishing a feedback loop that will help with refining and improving implementation.
- Consider an analysis of the costs of the DSD program along with evaluation of the program's effects, so that it might be possible to make judgments about the program's cost effectiveness relative to other programs or interventions the district could potentially implement.

Additional implementation data, collected as part of the ongoing evaluation of the initiative, will likely provide additional recommendations for improving the initiative. In addition, the district should consider the following steps in planning and carrying out a future evaluation of the DSD initiative:

- Consider the Theory of Change presented in this report, and refine it if necessary to ensure it is an accurate model of the DSD program.
- Use the Theory of Change as a framework for identifying measurements related to the various causal pathways, changes in behavior, and outcomes described in the diagram.
- Collect the relevant data over time.
- Monitor data for changes in outcomes of interest and explore all possible reasons why effects may or may not be found related to these outcomes.

The focus of the last four recommendations is for formative evaluation, because to design a persuasive evaluation around the limiting factors of Quaker Valley's implementation may not be feasible, considering the great expense and need for participation of additional school districts.

ACKNOWLEDGMENTS

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INTRODUCTION

In recent years, technology use in educational settings in the United States has become commonplace. Students and teachers report frequent use of computers in schools and classrooms for educational purposes, and nearly all schools and classrooms are connected to the Internet (see Fouts, 2000; Kleiner and Farris, 2002). The importance of educational technology has been emphasized by a dramatic growth in funding for technology initiatives and the emergence of government grants and other programs supporting educational technology programs (Dickard, 2003). As part of the growing trend to integrate technology into classroom settings, educators have sought new and innovative applications of technology in education. In particular, efforts to integrate use of laptop computers into classroom practice seek to enhance student access to computer technology by increasing the ready availability of technology for use at school, and in some cases, outside of school. Yet, as the number of new technology-based initiatives grows, little empirical research has been done to examine the implementation of these initiatives and their effects on students and teachers. The present study seeks to investigate one such innovative technology program—the Quaker Valley Digital School District (DSD) initiative—by providing a clearer understanding of the implementation and impacts of the initiative and suggesting possible methods for a future, more comprehensive evaluation of the technology program.

BACKGROUND: DIGITAL SCHOOL DISTRICT INITIATIVE

In September 2000 the Pennsylvania Department of Education announced a statewide competition to select and fund "Digital School Districts." As part of the DSD initiative, selected districts are intended to serve as models, or living laboratories, for innovative uses of technology to redefine and improve teaching, learning, and the management of educational systems. The initiative intends to test real-world applications of educational technology aimed at changing the way teaching and learning occur, going far beyond simply mechanizing current educational practice. The goals of the initiative include developing a new educational paradigm enabled by technology and systematic reform; increasing student achievement related to the Pennsylvania Academic Standards;

increasing the appropriate and effective use of technology in teaching, learning, and managing schools; developing strategies to overcome challenges while maximizing the benefits of educational technology; bridging the "digital divide" within communities; developing partnerships with world-class companies and education institutions; and serving as a model of the innovative use of technology to other schools (Pennsylvania Department of Education, 2000, p. 5).

Quaker Valley School District was one of three districts selected from the initial pool of 77 applicants to receive funding to become a Digital School District, receiving an award of $4.1 million in state funds in February 2001 to support a two-year program. Situated in Allegheny County, Pennsylvania near the city of Pittsburgh, Quaker Valley is a district of just under 2,000 students spread across four schools. Key technologies as part of Quaker Valley's proposal for the DSD initiative include the provision of a laptop computer to each student in grades 3–12, wireless networks in all district buildings and several local sites within the community, and wireless Internet connections in the homes of all students in grades 3–12. Implementation of the DSD plan began in summer 2001.

As part of Quaker Valley's proposal, the district planned to conduct both formative and summative evaluations of the DSD initiative. As of the writing of this report, the district is beginning the third year of implementation of the DSD initiative and is currently considering additional years of implementation. With the possible continuation of the project, the district has also considered conducting a comprehensive evaluation of the project in future years.

DISTRICT CONTEXT

The Quaker Valley School District serves 11 suburban communities located about 12 miles northwest of Pittsburgh, Pennsylvania. The district has two elementary schools, Edgeworth Elementary and Osborne Elementary, a middle school, and a high school.

Table 1 provides demographic and enrollment data describing Quaker Valley's student population. Total enrollment in the district in the 2002–2003 school year was slightly less than 2,000 students, with an 11 percent minority student population. Black students are the only minority group representing more than 2 percent of the student population. In recent years, the district has been growing about 3.2 percent per year and becoming slightly more diverse. In the last four school years the district-wide percentage of low-income students ranged from 10 to 12 percent,

Table 1

Quaker Valley School District Demographic and Enrollment Data

Enrollment Demographics		1999–2000	2000–2001	2001–2002	2002–2003
Total enrollment		1801	1839	1908	1978
Minority enrollment	Black (non-Hispanic)	6.8%	7.9%	7.5%	8.1%
	Asian/Pacific Islander	1.1%	0.9%	1.0%	1.7%
	Hispanic	0.3%	0.7%	0.6%	1.2%
	Native American	0.2%	0.1%	0.0%	0.2%
Meal subsidy eligible		11.9%	9.7%	11.4%	12.1%
Special education		11.1%	10.7%	11.8%	12.4%

which is significantly less than the statewide average of 31 percent.[1] Over the past four years, the district-wide attendance rate has averaged 95 percent, which is similar to the statewide average of 93 percent. In 2002, when reporting of disaggregated attendance rates began, minority students in Quaker Valley had similar attendance rates to the district average. Quaker Valley's graduation rate was 96.1 percent in 2002.

To describe average achievement levels in Quaker Valley we explored trends in performance on the Pennsylvania System of School Assessment (PSSA) math and reading tests. PSSA tests are administered to all students in grades 5, 8, and 11. Starting in 2000–01, the state also reported percentages of students in each of four performance-level categories: below basic, basic, proficient, and advanced.

Figure 1 shows the percentages of students scoring proficient or advanced, the two higher performance categories, on the state PSSA exam in mathematics, broken down by grade and school over the three years where performance level data are available. As Figure 1 illustrates, the district is consistently high achieving. For example, statewide about 49 to 56 percent of students across grade levels scored proficient or advanced in mathematics in 2003, while across Quaker Valley's four schools the percentages in these categories ranged from 69 to 85 percent. In addition, the significant percentage of students scoring in the advanced category is noteworthy. In 2003, 35 to 46 percent of students across the four schools

[1]Statewide averages for percentage low-income and attendance cover the years 1999–2000 through 2001–2002, the most current statistics available at press time.

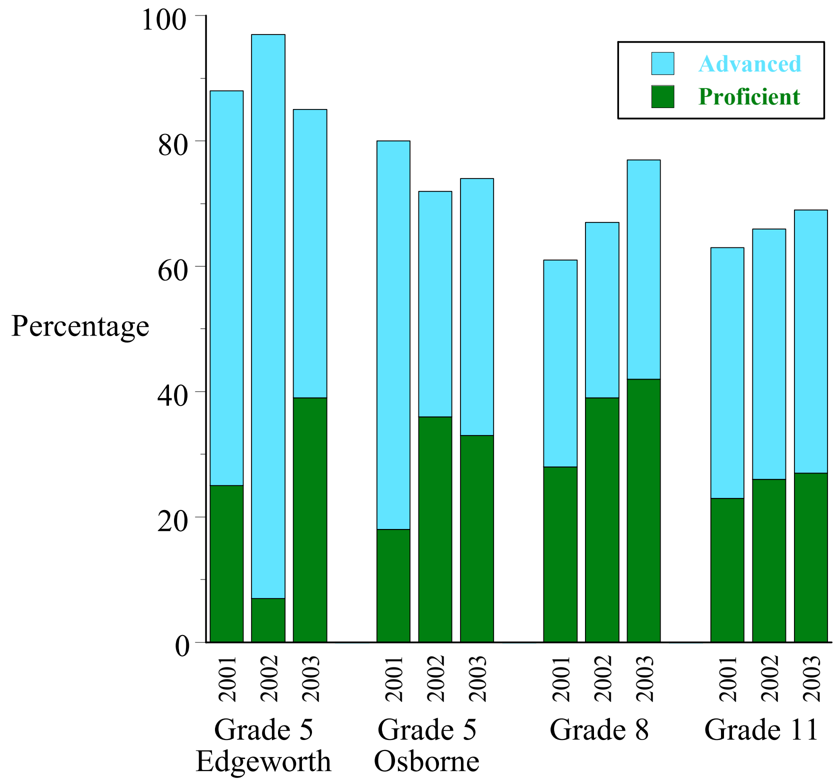

Figure 1—Percentage of Students Scoring Proficient or Advanced on PSSA Math Exam, 2001–2003

scored in the highest category, as compared to 19 to 28 percent across the same grade levels in the state of Pennsylvania as a whole.

Similar trends are seen when examining reading performance on the PSSA exams, as shown in Figure 2. The district consistently has a higher fraction of students in the proficient or advanced categories than the statewide averages. For example, statewide about 58 to 63 percent of students scored proficient or advanced in reading in 2003, while at Quaker Valley the percentages in these categories ranged from 66 to 84 percent.

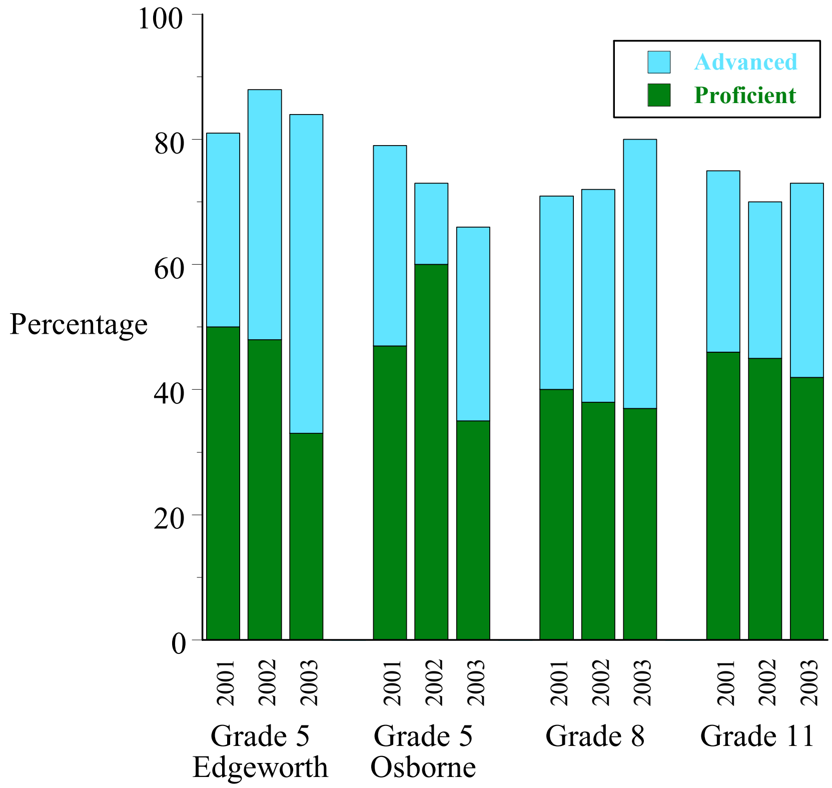

Figure 2—Percentage of Students Scoring Proficient or Advanced on PSSA Reading Exam, 2001–2003

DESCRIPTION OF RAND STUDY

The purpose of this study is to provide an initial evaluation of the implementation and impacts of Quaker Valley's DSD initiative as of the end of the second year of implementation, as well as provide a conceptual framework and guidance in planning a future, comprehensive evaluation of the project's continuation. To accomplish this task, the RAND Corporation proposed three research activities:

1. Review relevant literature on technology use in the classroom and the links between technology use, instructional practice, and student performance. Based on this literature and data describing the characteristics of Quaker Valley's project, develop a theory of action that describes the nature of technology use and the mechanisms

through which technology impacts district and community members in Quaker Valley.

2. Review qualitative data collected by RAND in the form of interviews, focus groups, and classroom observations, as well as existing data collected by the district and the project's internal evaluator, to assess project implementation and impact.

3. Formulate a set of research questions and a research design that could guide a future in-depth evaluation of the project's continuation.

Data Sources

The data available for the RAND study consisted of qualitative data collected during a three-day site visit in March 2003, along with project planning documents, demographic and achievement data collected by the state department of education and the district, implementation data from project reports and other documents, and summaries of surveys administered by the project's formative evaluator.

During the site visit, RAND researchers visited each of the district's four schools and interviewed the principals, observed classrooms, and held focus groups of teachers and students. The researchers also interviewed central office administrators and technology staff, and held evening focus groups of parents. In sum, 14 administrators and district-level technology staff were interviewed, and 33 students (grades 4–12), 33 teachers (grades 3–12), and 11 parents (of students in grades 3–12) participated in focus groups. Thirty-eight classrooms were briefly observed.

The planning documents provided to RAND included copies of a ten-page vision statement written prior to the district's grant proposal, the grant proposal itself, and the district's strategic plan.

Demographic and achievement data are publicly available at the Pennsylvania Department of Education Web site. This site includes scaled score data for each of the district's schools on the Pennsylvania System of School Assessment (PSSA) math and reading tests administered in grades 5, 8, and 11, dating back to 1995–96. Data are also available on a recently implemented writing test. The state has also published yearly school profile documents since 1995–96. The school profile contains statistics on demographics, enrollment and enrollment stability, class size, attendance rates, graduation rates, school staff and programs, disciplinary incidents, dropouts, grade retentions, and participation in Advanced Placement and college entrance exams.

The district also supplied summary data from Educational Records Bureau (ERB) exams administered to all students in grades 3–9 through the 2001–02 school year; additional information on enrollment broken down by grade, race/ethnicity, and gender; special education enrollment; free/reduced price lunch eligibility; attendance; and violence/weapons incidents.

Implementation data were available from a five-page chronological narrative about implementation and a two-page narrative description of technical implementation of the computer network and servers, written by district administrators; the project's parent/student handbook, which includes policies and a code of conduct; five reports prepared by the district for its funding agency, describing implementation progress and program activities; computer repair data, broken down by grade level; counts of attempts to load web pages that were blocked by content filtering software; a list of briefings held for visitors; summaries of visitors' post-briefing questionnaire responses; and summary reports of survey data from the formative evaluator.

The formative evaluator's surveys included: a survey of students and teachers in spring 2002, covering technological awareness, competency, use, and support for teachers; a survey of professional staff participating in an in-service program in August 2002; and a survey of parents in spring 2003, covering usage by students and parents of the home-school connection, problems with the connection, and parent perceptions of value of the connection and increased technology in general. In addition, the formative evaluator conducted two other surveys in spring 2003 that were not supplied to RAND: a survey of students and teachers; and a survey of principals and assistant principals.

Limitations of the Study

Several factors related to available data limited the types of analyses conducted for this study. First, RAND officially began its relationship with the district late in the second year of DSD implementation; therefore, we were unable to influence the collection of baseline data or formative implementation data during the first and second years of the project. Second, RAND was not given access to all available implementation data. For example, surveys of students and teachers administered at the end of the second year of implementation were not released to RAND for the purpose of this study. Thus, we were not able to consider changes or trends in project implementation measures from the first to the second year. In addition, limited resources for the RAND study confined our work to a short period of time and allowed us to collect only a limited amount of primary data concerning the DSD initiative.

The analyses and findings contained in this report represent a limited group of analyses conducted given the available data and time constraints of this study and are not intended to be comprehensive. They focus primarily on analysis of the qualitative data collected by RAND and include selected analyses of achievement and other implementation data provided to us.

Organization of the Report

The remainder of this report is organized as follows. We first discuss the conceptual framework guiding this study and proposed future studies of Quaker Valley's technology program, including a review of relevant research literature and a description of the Theory of Change underlying the Digital School District initiative. Next, we describe the status of the DSD initiative as of the end of Year 2 by presenting findings related to the implementation and impact of the project. We conclude with a discussion of plans for a future, more comprehensive evaluation should the district choose to continue the DSD initiative.

CONCEPTUAL FRAMEWORK

REVIEW OF EXISTING LITERATURE

As part of RAND's work for the Quaker Valley School District, we reviewed research literature on a number of issues relevant to school laptop program design, implementation, and evaluation. We reviewed major program evaluations from U.S. school laptop programs, as well as a sampling of international laptop studies, including work from Australia, Germany, and Great Britain. We also looked at research on educational technology more broadly, particularly in a number of areas relevant to laptop programs. Because this is a broad field of study with a voluminous literature in recent years, we focused on a number of key research reviews, syntheses, and meta-analyses. Our study was not intended to be comprehensive, but does seek to convey a broad consensus view of the promise and perils of technology, and laptops in particular, in K–12 education.

One key lesson we learned from our review is the need for future research and evaluation of educational technology and laptop programs to be rigorous and relevant. As Fouts (2000, p. 2) notes in his review of the literature, "Our current knowledge of the educational affects [sic] of technology is rudimentary at best." This is because research on educational technology has often been fraught with a variety of problems. Oppenheimer (1997), a prominent critic of educational technology initiatives, derides nearly all of the current literature: "The circumstances are artificial and not easily repeated, results are statistically unreliable, or, most frequently, the studies do not control for other influences, such as differences between teaching methods."[2] Many of these concerns are borne out in the literature on laptop programs: most laptop programs are embedded in larger school reform efforts, which makes it difficult to differentiate the effect of laptops from the effect of other changes; most lack valid comparison groups or baseline data, making the tracking and attribution of changes nearly impossible; and statistical techniques are generally fairly rudimentary (Penuel et al., 2002), making interpretation of changes quite challenging. Given all these problems, our review concurs

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[2]Quote is from an unpaginated web document.

with Fouts's (2000, p. 16) assessment that most of the existing studies on laptop programs do not meet standards of "rigorous empirical testing." Most of the research to date is suggestive rather than conclusive, which is important to bear in mind both in reviewing the existing literature and in thinking about further studies and the ways in which they might add to and improve on what has come before.

We begin our review by summarizing major trends in and uses of educational technology. We then provide an overview of the major outcomes expected from educational technology use in general, including potential effects on student learning, technological proficiency, equity, and educational transformation. We examine the rationale behind implementing laptop programs in particular, discussing issues such as computer density, home-school connections, parental involvement, and students' study habits. A more intensive discussion of the potential for laptops to enhance students' academic achievement follows. Finally, we turn our attention in this review to issues related to laptop program design and implementation, with a focus on potential building blocks for a successful laptop initiative.

Current Trends in Educational Technology

The widespread dissemination of technology in American schools and the introduction and implementation of new and innovative applications of technology in education have been major trends in recent years. Educational technology has been a major budget priority at all levels, receiving an estimated total of $6 billion in spending in 2000. Current federal programs include $700 million in Enhancing Education Through Technology block grants as part of the No Child Left Behind Act of 2001, and the Federal Communications Commission's $2.25 billion E-Rate telecommunications discount program for schools and libraries (Dickard, 2003).

As a result of these and many other initiatives, computers and the Internet are now nearly ubiquitous in our schools. As of 2001, American public schools housed more than 10 million computers, with 99 percent of schools and 87 percent of classrooms connected to the Internet, and one Internet-wired computer for every 5.4 students (Kleiner and Farris, 2002). Pervasive educational technology has increased access and use to unprecedented levels. Ninety-seven percent of teachers reported using computers for educational purposes in 2001, while 53 percent reported using software in their classroom instruction (Fouts, 2000).

Experts on educational technology have identified a number of potential uses for technology in schools (see Means, 1994; Glennan and Melmad, 1996; Fouts, 2000; Levin and Arateh, 2002). Many of the first educational technology applications focused on instructional delivery to supplement or replace books and traditional instruction. Most examples of such computer-assisted learning applications present non-dynamic content lessons and/or offer opportunities for students to drill and practice skills, often in game-like environments.

Educators have also been exploring the potential for educational technology to act as a transformational agent and a learning tool in support of non-traditional instruction. Examples of these types of applications include computer simulations that students can dynamically manipulate for deeper understanding of content matter; tutoring applications that are able to customize instruction based on a cognitive model of the student's knowledge (Anderson et al., 1995); new informational tools such as CD-ROM encyclopedias and the Internet, which can facilitate access to up-to-date and relevant resources; communications applications such as email and video teleconferencing that can expand the classroom community; and productivity tools like spreadsheets and databases that can be used as part of problem-solving activities or software to create "published" student work.

Finally, educational technology can be used to enhance teacher productivity. Applications such as PowerPoint, for example, can offer support for instructional delivery, while database or spreadsheet applications can aid in teachers' administrative duties. In addition, tools such as email and the Internet can create new avenues for teachers to communicate with students, parents, and their colleagues.

Links Between Educational Technology and Student Outcomes

The sustained interest of educators and policymakers in educational technology stems from expectations and early signs of a number of positive outcomes that researchers and theorists predict might result from the use of computers and other technologies in the classroom.

First, many educators and policymakers believe that educational technology will help to increase students' learning and academic achievement. A direct relationship between computer use and student achievement is challenging to identify and quantify since the link may depend on how the technology is used as well as on how achievement is defined and measured. Despite these difficulties, however, several meta-analytic studies synthesizing a wide range of research on educational technology programs have suggested the possibility of positive achievement effects. Meta-analyses of research on computer-aided instruction applications have found that these technologies help students learn more and learn faster, and general consensus in the field holds that, when combined with traditional instruction, computer-aided instruction can help increase student learning in traditional curriculum and basic skills (Kulik, 1994; Sivin-Kachala, 1998; Fouts, 2000). A more recent synthesis of educational technology projects aimed at linking home and school found mean achievement effect sizes that were comparable to those commonly reported for other reforms such as class-size reduction, tutoring, and parental involvement programs (Penuel et al., 2002). Since the issue of academic achievement gains is central to education reform in the United States, we will return to this point later.

A second major outcome that many policymakers and educators anticipate from educational technology programs is an increase in students' technological literacy to prepare them for the 21st century workplace. In one survey, parents of students in an educational technology program in the state of Washington overwhelmingly reported that increasing workplace skills was the primary reason they favored the use of computers in schools (Fouts and Stuen, 1999). Since computer work is a major component of many jobs in the American economy, it seems encouraging that some studies have shown that students in laptop programs possessed significantly better computer skills than their peers (Lowther, Ross, and Morrison, 2001; Rockman Et Al,[3] 1998). In addition to teaching specific computer literacy skills, educational technology may also help teach students a set of new "process skills" necessary in the workplace of the future; educational technology advocates McCain and Jukes (2001) hypothesize that these might include problem-solving and critical thinking, communication skills, technical reading and writing, and information literacy.

A third anticipated outcome of interest to educators and policymakers is the bridging of the "digital divide." Educational technology may help promote greater equity among students of different racial and socio-economic backgrounds by increasing access to information technology for all groups. A report from the U.S. Department of Commerce (2002, p. 88),

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[3]"Rockman Et Al" is the name of the firm that issued the report and is spelled as shown here.

for example, found that minority students and low-income students are much more likely to rely on their schools to provide their only access to computers and the Internet, and noted the "substantial equalizing effect of schools on both computer and Internet use as compared to use at home." Some evidence indicates that educational technology can help to bridge longstanding achievement gaps between different student populations. Stevenson's (1998, 1999) evaluation of a laptop program in Beaufort County, South Carolina, for example, found that laptop students who participated in the free and reduced price lunch program had such significant increases in Metropolitan Achievement Test scores that at the end of two and three years they were scoring as well as their non-laptop peers who did not receive free or reduced price lunch; the laptop program was found to have had a weaker and less significant effect on the achievement gap between racial groups. Such evidence linking access to achievement is relatively scarce, however, and awaits additional studies and evaluations for further confirmation. Still, it could be argued that providing equitable access to computers and the Internet is an important goal in and of itself.

Finally, advocates of educational technology argue that educators and policymakers should be interested in the potential of computers to revolutionize teaching and learning by freeing education from current constraints related to place, time, social class, the age of learners, the nature of teachers, and so on (McCain and Jukes, 2001). Some effects can already be seen; for example, Internet access affords teachers and students access to relevant and up-to-date information that would not otherwise be available to them (Levin and Arateh, 2002; MEPRI, 2003). Some critics, though, note that there are fewer controls on the quality of Internet information than on information from more traditional sources (U.S. Department of Commerce, 2002). In terms of time and place constraints, distance learning programs are being pioneered by a number of universities as well as a handful of public school districts and other educational institutions. Most studies in this field show no significant differences in learning outcomes between distance and traditional learning, meaning that students' can learn equally well in non-traditional formats (Russell, 1999), though outcomes other than academic achievement are less well understood. It seems likely that rapid improvements in educational technology will lead to other innovative educational programs in the future.

Student Laptop Programs

Rationale

As computers have become commonplace in schools and classrooms in recent years, interest has been growing among educators in school laptop programs that equip each student in a class, grade level, or school with his or her own laptop computer. Laptop programs were pioneered in Australia through Toshiba's SchoolBooks program, and were first adopted in the United States by postsecondary institutions like Drew University in New Jersey, while K–12 implementation was led by Microsoft's nationwide Anytime Anywhere Learning program, initiated in 1996 (Rockman Et Al, 1997). Laptop programs in some form have now been adopted by individual private and public schools, public school districts, and, in the case of Maine, an entire state. Researchers and advocates for school laptop programs point to a number of additional effects that may strengthen or supplement the positive outcomes anticipated from educational technology programs when laptops in particular are used.

First, universal laptop programs that include a large number of students in a classroom, grade level, or school help to increase computer density, which is related to both the amount and quality of computer use in instruction. Studies in recent years have found that students and teachers in classrooms with more computers are more likely to use computers in assignments and instruction and that the effectiveness of educational technology and its integration into classroom lessons is influenced by the level of student access to technology and the extent to which computers must be shared among students (Sivin-Kachala, 1998; Fouts, 2000; Smerdon et al., 2000). Compared with non-laptop classrooms, computer use in laptop classrooms has been found to be both more frequent and more educationally meaningful (Rockman Et Al, 1998, 1999; Lowther, Ross, and Morrison, 2001, 2003).

Laptop programs may also increase students' access to technology at home. One national study, for example, found that 7th grade students with laptops used computers at home ten times as much as their non-laptop peers (Rockman Et Al, 1998). Home computer use has been linked to both higher academic achievement and to greater technological proficiency (Rocheleau, 1995; Wenglinsky 1998; North Carolina Department of Public Instruction, 1999). Students in one national survey also indicated that teachers were sometimes prevented from fully incorporating computers and the Internet into assignments by the fact that not all students in their classes had access at home, so laptop computers may improve the integration of technology into instruction (Levin and Arateh, 2002). In addition, a laptop program may promote greater instructional integration, since having all students using similar machines removes compatibility issues that can arise when students use different platforms at home and at school (Rockman Et Al, 1997).

A related effect is the potential for laptop programs to increase parents' involvement in their children's education and to provide parents with opportunities to increase their own technological skills. National survey data show that parents view the Internet as an important resource for increasing family involvement in schools (National School Boards Foundation, 2000). Increasing computer access in students' homes may facilitate some parents' use of the Internet and other resources, as well as provide an avenue for parents and children to explore technology and related schoolwork and assignments together. One laptop program, for example, featured special opportunities for laptop training for parents and a program to use laptops as a means to facilitate communication among parents about issues of common concern (Smith and Anderson, 1994).

Finally, laptops may improve students' organizational skills and study habits. Students in one national survey, for example, indicated they were able to use computers and the Internet as a "virtual locker, backpack and notebook" enabling them to be more organized and to carry fewer books (Levin and Arateh, 2002, p. 13). Indeed, students and teachers in several laptop schools reported that laptops helped to make students better organized and more responsible (Rockman Et Al, 1998; Metis Associates, 2000). In some studies, laptops have been found to allow students to make better use of spare time—waiting for a ride home from school, for example—since they can do schoolwork anywhere and at anytime (Rockman Et Al, 1997). Students also frequently integrate laptops into both school and personal uses (McMillan and Honey, 1993). Perhaps as a result, students report that computers and the Internet helped them to better juggle the demands and responsibilities of school and their extracurricular activities. Such improvements, however, must be balanced against increased cheating, plagiarism, and other forms of poor study habits and academic dishonesty that were sometimes facilitated by computers and the Internet (U.S. Department of Commerce, 2003).

Links to Student Achievement

Of all these potential expected outcomes, most educators, researchers, and policymakers are most interested in increases in student learning and academic achievement, since these are commonly regarded as the core mission of public education. Researchers have sought to understand both how laptops might lead to achievement gains and whether such improvements actually occur.

One way in which laptops in the classroom might enhance academic achievement is through improvements in instructional practice. Specifically, many researchers and educators argue that the use of computers, and laptops in particular, may enhance and increase teachers' use of constructivist instruction and student-centered, knowledge-centered learning environments, which theoretical research suggests are most conducive to effective student learning (Bransford, Brown, and Cocking, 1999; Shaw and PCAST, 1998). Laptops may enable teachers to implement practices that theoretically contribute to achievement, such as more frequent assessment, immediate feedback, diagnostics, and individualized instruction (Slavin, 1995). As the U.S. Department of Education (1993) noted in one report, "Technology supports exactly the kinds of changes in content, roles, organizational climate, and affect that are at the heart of the reform movement."[4] Indeed, a number of researchers have found that access to computers can play a major role in determining the nature of students' educational experience. One meta-analysis of over 200 studies on educational technology found that technology-rich classrooms featured more student-centered learning, cooperative learning, and teacher-student interactions (Sivin-Kachala, 1998).

Numerous evaluations of laptop programs in particular have found important changes in instruction in laptop classrooms. For example, in one national cross-site evaluation of more than 20 different laptop programs, teachers reported more project-based, student-centered, and interdisciplinary teaching than before implementation of the laptop program. Teachers reported better collaboration among both students and teachers, as well as less use of large groups and lectures and more use of individualized learning and small groups. The most fundamental change found by the evaluation team was a shift in the role that teachers played in the classroom, from serving as transmitters of knowledge to instead acting as facilitators for student inquiry (Rockman Et Al, 1997; 1998). Similar findings have been reported from a number of other studies of individual laptop programs (MacMillan and Honey, 1993; Lowther, Ross and Morrison, 2001, 2003; Hill et al., 2002; MEPRI, 2003).

Still, results of the national evaluation were more suggestive of potential effects than predictive of universal outcomes. The researchers note considerable variation in the use of laptops in instruction across and even

[4]Quote is from an unpaginated web document.

within programs, which they argue indicates the flexibility of laptops as educational tools and the admirable willingness of teachers to experiment. They also found that the use of laptops varied by grade level and subject area, and changed considerably over time (Rockman Et Al, 1997, 1998). Other research supports the importance of time, suggesting that it may take teachers two to three years to become facilitators of significant laptop use, and as much as five years to develop true expertise at technology integration (Newhouse, 2001). In addition, one study using videotaped classroom observations found that the actual instructional changes observable in classrooms may be less profound than is commonly reported by students and teachers on the surveys and questionnaires used for most previous laptop studies (Schaumberg, 2001). Finally, some critics worry that technology may actually narrow schooling and instruction and end up neglecting important learning opportunities in the human and physical worlds (Oppenheimer, 1997). Further research utilizing a variety of measures and methods and including efforts to disentangle such variations in the use and integration of laptops over grade levels, subject areas, and time will help advance understanding of the role of laptops in instructional change.

A second mechanism through which laptops might help increase student learning and academic achievement is through their effect on student motivation. Prior research has linked student engagement and autonomy to grades and achievement (see, for example, Connell, 1990). In addition, several studies found that students with laptops had better attendance records than their non-laptop peers, though this may be due to pre-existing characteristics of students who participate, rather than a causal relationship (Metis Associates, 2000; Stevenson, 1998). In fact, nearly all previous research and evaluations of laptop programs report teacher, parent, and student perceptions of increased student motivation and engagement (Rockman Et Al, 1998, 1999; Metis Associates, 2000; Lowther, Ross, and Morrison, 2001, 2003; Hill et al., 2002; MEPRI, 2003). The national, cross-site evaluation, for example, found that laptop students were significantly more likely to report that schoolwork was "fun" and "interesting" than were their non-laptop peers (Rockman Et Al, 1998, p. 57).

Still, some researchers express concern that student motivation may decrease once the novelty of a new program and a new computer wears off (Penuel et al., 2002). One of the longest running evaluations, a seven- year study of a laptop program in a girls' boarding school in Perth, Australia, found that five years after receiving their laptops, only half the students in the oldest cohort still had their computers, and most used them for word processing only. Most did not regard the laptops as a useful learning tool, and just 23 percent wanted to use their computers more in school (Newhouse, 2001). Future research may help clarify whether such a loss of motivation is the inevitable result of decreasing novelty, or was rather an effect of poor implementation, poor integration of technology into the curriculum, or some other factor, such as the age of the students, the particular technology chosen, or obsolescence of the technology.

Of course most educational stakeholders are ultimately most interested in the impact laptops have on student learning, whether through instructional changes, motivational increases, or some other mechanism. Studies of a number of laptop programs throughout the United States and abroad do in fact suggest achievement effects for students in laptop programs in reading, writing, and/or mathematics. One line of evidence comes from student and teacher reports, which suggest that laptop programs are perceived to have a positive impact on writing skills, spelling, thinking processes, math and reading scores, the overall quality of student work, and long-term achievement (McMillan and Honey, 1993; Rockman Et Al, 1997, 1998; Stevenson, 1997, 1999; Hill et al., 2002).

Due to the subjective nature of self-reports, some researchers have taken a second approach to the problem by conducting cross-sectional comparisons of laptop students and their non-laptop peers on standardized tests or performance assessments. Laptop students in Beaufort County, South Carolina, for example, generally scored significantly higher than their non-laptop peers on the Metropolitan Achievement Test after two and three years (Stevenson, 1998, 1999). In an evaluation of the Anywhere Anytime Learning program, 7th grade laptop students were found to apply critical thinking skills more readily than their non-laptop peers during a researcher-administered problem-solving simulation, and scored significantly higher on an independently graded writing assessment; comparison of standardized test scores, however, did not reveal any significant differences between laptop and non-laptop students (Rockman Et Al, 1998, 1999). While such comparisons are encouraging in some cases, they do not necessarily point to the laptop program as the source of the difference, since they fail to take into account any preexisting differences between the two groups.

A third set of studies has attempted to use longitudinal student test scores to trace differences between laptop and non-laptop students over time in an effort to determine whether laptop students are able to learn more and/or faster than their non-laptop peers. Results from these studies suggest some positive effects, but are quite mixed. Students in a small pilot laptop program in New York City, for example, showed no significant difference from their non-laptop peers on the California Achievement Test math assessment prior to the implementation of the program, but had significantly higher scores than these peers two years later. However, other students who received laptops a year later in a scale-up phase did not achieve any gains in their math scores during their one year with laptops, while their non-laptop schoolmates made significant gains. In reading, students in the pilot program did not gain or lose relative to their non-laptop peers over two years, but students in the scale-up program maintained their CTB assessment scores over their year of program participation while the scores of their non-laptop peers declined significantly (Metis Associates, 2000). Students in a district laptop program in Michigan scored significantly higher than non-laptop students on a writing and problem-solving assessment two years after joining the program, despite the fact that they had scored significantly lower than the other students on a pre-program writing test. Interpretation of this result is muddied somewhat, however, by the fact that laptop students scored significantly higher than their peers on a pre-program science test (Lowther, Ross, and Morrison, 2003). The most consistent results were found in the Beaufort County, South Carolina program, in which laptop students maintained their composite Metropolitan Achievement Test scores over two years while their non-laptop peers experienced significant declines (Stevenson, 1998).

A number of factors cause concern about the strength of these results. First, the statistical analyses performed are relatively simplistic and, even in the longitudinal comparison group designs, fail to capture the outcome of most interest: the difference between groups in pre- and post-test score differences. Evaluation results to date also reflect a fairly short time frame, typically one or two years, despite the fact that some researchers have suggested that true change may require three years of implementation or more (Newhouse, 1999, 2001; Stevenson, 1998, 1999). Some researchers and educators have argued that standard pen-and-paper, multiple-choice tests such as those used in several of the cited studies may be inappropriate measures of the types of student learning expected to result from educational technology (Lowther, Ross, and Morrison, 2003; Rockman Et Al, 1999). Finally, some educators express concern about the impact of computers on student outcomes other than academic achievement; some evidence points to technology-related declines in attributes such as creativity, social development, and innovation (Oppenheimer, 1997). Future evaluations utilizing more powerful statistical methods, a longer time frame, and multiple assessments and indicators of a variety of outcomes could make important contributions in clarifying and strengthening these preliminary findings.

Thus, while existing studies show some positive effects of laptop programs, the results are often ambiguous and tentative, and are thus not conclusive. One reasonable interpretation of the research to date is that laptop programs *can* increase student achievement, but they do not in all cases; much depends on how they are used and other implementation and contextual issues. Another important avenue for further research is to incorporate details of program implementation as explanatory variables in order to differentiate the characteristics of successful and unsuccessful programs and offer further guidance to policymakers and educators as they design their own laptop initiatives in the future.

Variations in Program Design and Implementation

One of the first steps in creating a successful laptop program is specifying the program design. Existing laptop programs vary on a number of dimensions, including the scope of the program, the level of participation, the grade level and subject emphasis, and the supports provided.

The scope of current laptop programs varies widely, from single class programs to statewide initiatives like the Maine Learning Technology Initiative, which provides a laptop computer to all 7th grade students statewide. As Rockman Et Al (1997) notes in the evaluation of Microsoft's Anytime Anywhere Learning program, much of this variation depends on available resources and the existing state of technology in a given school, district, or state (see also Passey et al., 1999). Additional considerations include a number of trade-offs regarding depth versus breadth of implementation. A laptop program implemented in a single classroom might have heightened odds of success since resources could be carefully targeted and participants carefully selected for their enthusiasm and agreement with the program's philosophy; on the other hand, such a program might have limited potential to spark widespread educational reform, and might also have to contend with concerns and complaints about educational equity. At the opposite end of the spectrum, a statewide program such as Maine's has high visibility and a large potential to bring about significant change in educational practices, and enhances equity by providing access to everyone. However, the program must contend with contexts that differ across sites and that make targeting resources more difficult, as well as some participants who will inevitably be resistant to the program.

Who participates in laptop programs also differs across initiatives. Universal access, where laptops are mandated for all students in a school, seems to be the ideal for which most programs strive. Many private schools have adopted this model, since they are often able to demand that parents purchase specific academic supplies, including computers. Public schools who wish to pursue this model generally have depended on considerable grants from foundations to support the initial purchase of laptops, but must then contend with much larger sustainability concerns than private schools. Some public schools have instead instituted voluntary laptop programs, where parents can choose to purchase or lease a laptop for their child; in some cases, students are then enrolled in special laptop classes, while in others they use their laptops in regular classes alongside non-laptop peers. These programs raise some equity concerns if not all parents can afford the laptops, so some schools also offer financial aid of some sort. The more diffuse model, with laptop students in classes with non-laptop students, is generally not regarded as the most effective implementation for transforming instruction. This model is also likely to create much greater classroom management and instructional planning challenges for teachers (Stevenson, 1999).

The grade level of the participants is another variable in program design. Most existing laptop programs tend to focus on 5th through 8th grade students, though a few do extend from 3rd grade through 12th grade. One study of a laptop program in Australia found considerably less enthusiasm and use among 12th graders than 8th graders, which the author credited to the fact that upper-level schoolwork focuses more on teacher-directed learning and factual recall, while middle school instruction tends to feature more reform-oriented instruction that is better suited to laptop learning. The author also speculated about the influence of British tertiary exams, suggesting that since laptops were not proven to affect achievement on such high-stakes assessments, teachers and students in the upper grades may have shied away from using them extensively for instruction (Newhouse, 1999). American students have similar concerns regarding the SAT/ACT in high school; however high-stakes testing may come to pose similar problems in middle schools as well, as the No Child Left Behind Act introduces annual assessments in 3rd through 8th grades.

A few programs focus laptop use on specific subjects. Project PULSE in Roselle, New Jersey, for example, was targeted at English and science learning (McMillan and Honey, 1993). Most laptop programs, however, are cross-curricular, with laptops intended to be used in all academic subjects. Even in cross-curricular programs, however, some subjects seem better suited to laptop use than others. One researcher found that laptops were most used in English, design and technology, computing electives, and social sciences, and were least used in mathematics, Japanese, French, and science (Newhouse, 1999); other researchers have also found variation in use across subjects (Rockman Et Al, 1998; Hill et. al, 2002; MEPRI, 2003).

A final program design variation virtually ignored in the research literature to date is the equipment used. While the choice of platform is in some cases determined by sponsorship possibilities—Microsoft, Apple, and Toshiba are all involved in various school laptop initiatives—other schools are able to make more deliberate decisions regarding benefits and drawbacks of various systems. The laptop hardware, as well as the software, seems likely to have some influence on the success of the program, but few laptop studies have examined the implications of these choices, beyond describing the hardware and tracking what types of applications are most often used; word processing packages, web browsers, spreadsheets, and presentation applications such as PowerPoint generally come at the top of such lists (Rockman Et Al, 1997, 1998, 1999).

Key Aspects of Program Implementation

Beyond handing out laptops to some set of students, it is important to consider what else might be necessary to ensure the success of a laptop program. As the tentative and at times contradictory results from previous laptop studies suggest, technology on its own does not cause change. The Benton Foundation echoed the concerns of numerous researchers, pointing out in its report on sustainability in educational technology, "Merely purchasing technology resources has not—and could not have—changed the character of education" (Keane et al., 2003, p. 27). Instead, educational technology advocates argue that computers need to be viewed as cognitive tools in the process of systemic change, not as an add-on for traditional instruction (Fouts, 2000; Angeli, 2003; McCain and Jukes, 2001). One researcher points out that technology serves as an "amplifier," capable of making good practices better, but bad practices worse (cited in Oppenheimer, 1997). Thus introducing a successful new laptop program must extend far beyond simply purchasing equipment. New Jersey's Statewide Systemic Initiative offers a cautionary tale: the $15 million, four-and-a-half-year educational technology effort yielded no achievement gains of any type, causing the program evaluators to conclude that "the strategy—pay for everything and hope for the best—was, at the same time, expensive and limited" (Fenster, 1998, p. 28).

Though the existing research literature on school laptop programs is unfortunately sparse on discussion of implementation issues, a number of researchers and advocates for educational technology have offered ideas for successful and effective implementation, often based on research from other areas of educational reform (see, for example, Angeli, 2003; Keane et al., 2003).

Effective leadership is often mentioned as a vital component of successful technological integration. Students in a national survey reported that it was their school leaders, more than their individual teachers, who set the tone for the use of the Internet in their classrooms (U.S. Department of Commerce, 2002). Existing research suggests that effective leaders must communicate a coherent instructional framework, including the role of technology within that framework. Case studies of a number of schools introducing technology-rich initiatives found that such a clear framework was the single most important factor in successful technology integration (Sanchez and Nichols, 2003). School leaders must also exercise considerable vision in planning for technology programs that will remain relevant in the future. McCain and Jukes (2001) argue that the dizzying pace of technological advancement requires educators to be visionaries who can radically rethink education in light of continual new developments. Finally, research suggests that it is essential for leaders to meet the needs of their school team for support throughout the process of implementation.

One important type of support is targeted professional development that allows teachers and other staff members to learn about new technology and how to use it in the classroom. As of 1999, just 10 percent of teachers felt very well-prepared to use computers and the Internet for instruction, while 13 percent felt not at all prepared, a potentially problematic statistic since research has shown that poor feelings of preparation are significantly linked to low use of technology in the classroom. Fortunately, the same study showed that teachers' ratings of their preparation for using computers are significantly linked to the amount and quality of technology-related professional development that they receive, so offering teachers training on integrating laptops into their instruction may enhance the success of the program considerably (Smerdon et al., 2000). Angeli (2003) reports that professional development should be congruent with the school's vision, should focus on both technical and pedagogical integration skills, and should offer ample opportunities for teachers to practice with technology.

In addition to formal training opportunities, case studies suggest that fostering professional learning communities is also important for successful technology integration (Sanchez and Nichols, 2003). Crucial for both formal and informal professional development, of course, is time.

Teachers involved with a number of technology-intensive initiatives report that integrating technology into the curriculum requires a significant amount of learning, planning, and additional curriculum development work; lack of adequate time for such activities serves as a major barrier to successful implementation (Smerdon et al., 2000; Penuel et al., 2002). Rockman Et Al's (1997) national evaluation noted that sites that provided adequate lead time and a relatively slow start to implementation seemed to fare better than others. Finally, research indicates that students, too, may require targeted computer instruction and development opportunities to make the most of their machines. Educational reform experts and senior staff at one laptop school found technological literacy among students to be a necessary component for satisfactory program implementation (Newhouse, 1999). Students at another laptop school, however, noted that while they used their computers more in core classes, they experienced a decline in learning opportunities specific to computer use, for example instruction in keyboarding or other computer applications (Hill et al., 2002).

Successful implementation of technology-intensive initiatives also requires a high level of technical support. As Fitzgerald (2003, p. 24) notes in a Benton Foundation report on sustainability, "Schools can hardly brag about achieving a computer ratio of one computer to every five students if the computers are only up and running 80 percent of the time." Empirical evidence from one laptop program suggests that Fitzgerald's estimation of downtime was not far off the mark: the average computer of 13-year-old students had been down for repairs 0.75 days each week, while an average of 13 percent of students, or about 3 students per class, had their computers in for repairs at any given time (Newhouse, 1999, 2001). Determining adequate levels of support staffing and resources depends in part on how "high-tech" or "low-tech" a school or program is. Some industry formulas suggest ratios of one support staff for every 50 to 75 computers (Fitzgerald, 2003). For a program aimed at distributing laptops broadly—perhaps even universally—across even a fairly small school, this would seem to require adding one or more new, full-time technology professionals to the staff. Support can come in other forms, too, such as outsourced services, help desks, or Web sites with answers to frequently asked questions. A 2002 study by the National School Boards Foundation (NSBF) revealed that 54 percent of districts nationwide also utilize students' skills to fulfill technical support needs. This trend seems somewhat controversial; while the NSBF notes that it provides students with valuable leadership opportunities, others have expressed concerns about computer access and privacy issues, the potential for mischief, and the possibility of subtle exploitation of students (Fitzgerald, 2003). Whatever the source, studies confirm that adequate and responsive technical support is required if new technology programs are to be successfully implemented.

In addition to providing such support, schools must also carefully consider the role of computers in the classroom and the curriculum if they are to be successfully integrated in ways that lead to achievement gains. Students in a national survey on technology in schools reported that the typical use of the Internet for instruction was neither exciting nor engaging (U.S. Department of Commerce, 2002). Numerous researchers and educators have emphasized that remedying this problem and maximizing the potential power of technology to enhance instruction will require some fairly radical reforms of learning environments, curriculum, and assessment.

Reform-oriented learning environments are often characterized as learner-centered and knowledge-centered classrooms. Along the same lines, a survey of education reform experts and senior staff at a pioneering laptop school found that adequate implementation of a laptop program requires at a minimum a variety of teaching strategies, opportunities for independent learning, and teachers acting as facilitators of inquiry rather than as the sole sources for learning (Newhouse, 1999).

The curriculum that is taught in such learning environments is equally important. Case studies of technology-rich schools point to the importance of a curriculum that is closely and consciously aligned with the school's shared instructional framework (Sanchez and Nichols, 2003). Educational technology theorists suggest that curricula in technology-rich schools should be project- and problem-based, and should be linked to real world phenomena (Angeli, 2003). Experts report that classroom and homework activities should be practical and relevant, and feature regular feedback that helps motivate students (Newhouse 1999). Finally, advocates recommend that the curriculum should be designed so that technology is not limited to "computer classes" or supplementary instruction, but is instead strongly integrated into core educational priorities (Keane et al., 2003).

In addition, experts suggest that innovative learning environments and curricula be complemented by new types of assessment as part of a technology implementation plan. Researchers have suggested that traditional forms of assessment, particularly standardized testing, are inadequate measures of the types of learning that computers are expected to foster. Instead, experts suggest that assessments in technology-rich classrooms should be closely aligned with the skills and knowledge that computers help to foster, and should also be dynamic in nature and on-going, to provide students and teachers with continuous feedback to help guide instruction (Fouts, 2000; Peneul et al., 2002).

Research suggests successful implementation and integration include substantive partnerships with a variety of stakeholders and collaborators. Case study research on the involvement of external organizations in educational technology initiatives found that the partnerships aligned with the school's instructional framework could leverage considerable resources for increasing student achievement (Sanchez and Nichols, 2003). For example, Project PULSE was able to use partnerships with local business and business organizations to receive no-cost Internet access, a grant for additional phone lines, and a grant for developing inquiry-based science curriculum (McMillan and Honey, 1993). In addition to business partnerships, other important potential collaborators and stakeholders include universities and community organizations as well as parents and students, whose commitment and enthusiasm can be vital to a laptop program's success (Rockman Et Al, 1998; Keane et al., 2003). However, it is important to consider whether the resources invested by external organizations in novel technology initiatives will scale up as these initiatives become more commonplace.

An additional concern cutting across all of these building blocks is the issue of sustainability. While most laptop programs require an intensive initial injection of resources for purchasing hardware, training teachers, hiring new personnel, and so on, nearly all also depend on ongoing flows of both financial and other resources to continue their success into the future. On the financial front, for example, some principals in Maine reported that the statewide middle school laptop initiative had proved unexpectedly costly due to recurring expenses such as insurance, replacement and repair, and consumable computer and printer supplies (MEPRI, 2003). To the extent possible, it is necessary to consider and plan for all such ongoing resource infusions prior to program implementation, since such resources must either be diverted from other school programs or found through fundraising and cost savings in other areas. Another sustainability challenge reported in a number of laptop programs is the issue of equipment obsolescence, where laptops that were top-of-the-line when students were in 6th grade may be old "clunkers" by the time they reach 8th grade (Penuel et al., 2002). It may be necessary to anticipate and deal with these and other challenges from the earliest stages of program implementation if a laptop initiative is to be successful for years into the future.

In sum, existing research on educational technology programs, and laptop programs in particular, suggests several possible outcomes for students, parents, and teachers that may result from the integration of technology into educational settings. However, current research for the most part is suggestive only, and does not allow for conclusive statements about the effects of technology, instead calling for more extensive and rigorous evaluations of the impact of educational technology programs. In addition, while researchers have identified several aspects of program implementation that may be key to the effectiveness of a technology initiative, additional research considering characteristics of implementation and the effects of differing implementation strategies on program success is warranted.

Nonetheless, the outcomes posited by past research and the hypothesized mechanisms through which educational technology programs may bring about such outcomes inform the theory behind the DSD initiative in Quaker Valley. Building on many of the ideas found in past research, we next turn to a discussion of a proposed Theory of Change underlying the DSD initiative. This includes various changes in behavior that were expected of members of the district as a result of the technology initiative, as well as outcomes for students, parents, teachers, administrators, and community members that were ultimately expected to result from the implementation of the program.

THEORY OF CHANGE UNDERLYING THE DIGITAL SCHOOL DISTRICT INITIATIVE

Based on a review of Quaker Valley's DSD proposal and other written documents describing the initiative, and our conversations with members of the district, we have constructed a diagram to describe the district's Theory of Change for the DSD initiative (see Figure 3). The diagram attempts to show the causal path through which the district believed the DSD initiative would bring about changes in behavior and subsequent outcomes within the district. The arrows in the diagram represent a hypothesized path showing where a particular input may lead to the shown output, or outcome, for various members of the district or community.

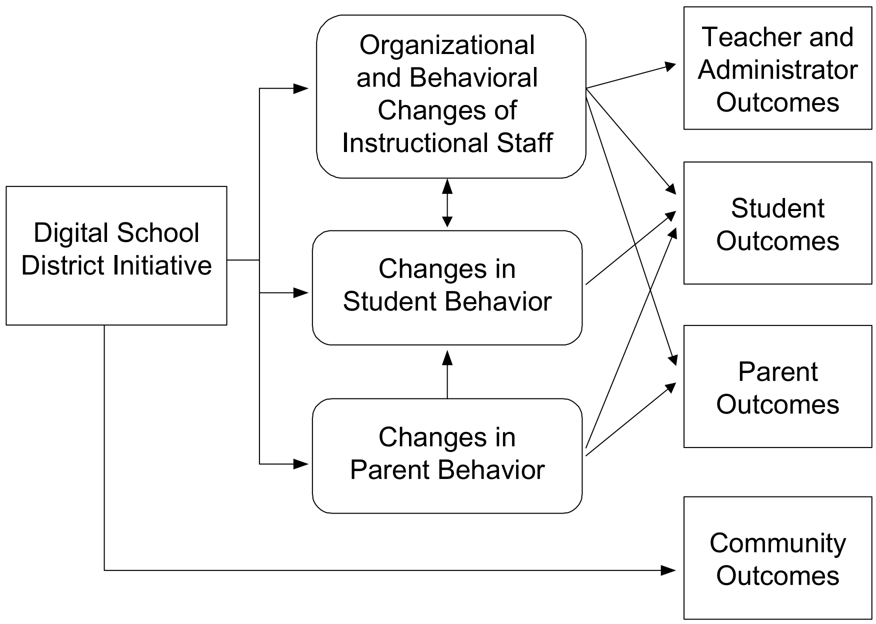

Figure 3—Quaker Valley Digital School District Theory of Change

In short, the district hypothesized that implementation of the DSD project would bring about changes in behavior on the part of instructional staff, including teachers and principals, and students and parents, in essence allowing or causing members of the district to act in new and/or different ways. Because of these changes in behavior, as well as other changes expected to happen to the organization or structure of teachers' and administrators' work, the district predicted various outcomes for members within each of these groups.

For example, it was thought the technological advances would allow teachers to organize and manage their administrative responsibilities more efficiently and effectively, thereby providing them with more time for instruction and more accessible, usable data on student progress. This change in how teachers go about their daily work and the resources available to them could result in many outcomes: teachers themselves may learn and implement new or different instructional methods; students may receive additional one-on-one instruction from teachers in areas where they need assistance, possibly leading to improved achievement; and parents may experience increased communication with teachers about student progress.

Similarly, the laptop computers, wireless Internet connections, and other advanced technologies of the DSD initiative were expected to change student behavior both in school and at home. Students may go about their work in new ways, experience new kinds of assignments, or use new or additional resources. In turn, these changes to student behavior may lead to various outcomes identified in previous research, including improved competence with types of technology; greater accessibility to learning opportunities in other communities or schools, such as through distance learning programs; greater motivation to engage in school work; or increased achievement.

Finally, components of the DSD initiative, such as accessibility to their child's laptop computer, the wireless home Internet connection, and web-based grade management tools, were expected to promote changes in parent behavior. For example, parents may take a more active role in monitoring student assignments and/or performance online, or communicate with teachers or principals more frequently via email. These changes may lead to outcomes for parents, in terms of technology use and competence and increased knowledge regarding their child's progress, as well as outcomes for students, who may benefit from an increased participation on the part of parents.

While groups of actors are represented independently in the diagram for the purpose of clarity, it is important to note that members of each group interact with and influence members of other groups. This point is illustrated in the arrows leading to and from changes in behavior of the instructional staff and changes in student behavior, and in multiple arrows leading from a change in behavior of one group to outcomes for other groups. Finally, though the district expected the initiative to lead to outcomes for members of the community not associated with the district, specifically regarding accessibility and use of technology, it was not clear if there was an intervening step, or change in behavior, in the district's thinking that linked the initiative to the community outcomes. Therefore, the Theory of Change diagram shows a direct link between the DSD initiative and community outcomes.

We next present data describing the implementation and impact of the initiative as of the end of its second year, speaking to the behavioral changes and predicted groups of outcomes hypothesized in the Theory of Change. We will later return to consider this Theory of Change as a foundation for building a future evaluation plan.

CURRENT STATUS OF THE DIGITAL SCHOOL DISTRICT INITIATIVE

FINDINGS REGARDING IMPLEMENTATION OF THE DSD INITIATIVE

A review of data collected during a site visit to the district as well as existing survey data reveals both strengths and weaknesses in the implementation of the DSD initiative in its first two years. In the next sections we present findings related to four key areas of implementation. First, we address the use of technology at school by both students and teachers. We then discuss changes in instructional practice linked to the DSD initiative, focusing specifically on the integration of technology into the curriculum and the use of individualized instruction and assessment by teachers. We then turn to findings related to home connection use by students and parents, and finally discuss the management and technical support mechanisms and policies in place and how they relate to the successful implementation of the initiative.

Use of Technology at School by Students and Teachers

Students reported that use of technology in the classroom varied widely based on subject or content area. Whereas certain subjects lent themselves well to technology use, for example the use of word processing software in English or language arts classes, others had less readily available or explicit applications of technology. First, surveys administered to teachers and students by Carnegie Mellon University in April 2002 show that students reported a relatively high rate of use of technology in the class where they use technology the most. At the end of the first year of implementation, nearly all middle school students reported using technology once a week or more in the class where technology is used the most, while approximately three-fourths of high school students reported similar use. However, when asked a year later about technology use across all classes and subjects, students reported using technology in some form on a regular basis in certain subject areas and far less frequently, or not at all, in others.

According to the survey data, students reported high competency levels regarding their ability to use basic software applications by the end of the first year of implementation. Over 70 percent of middle and high school students reported they were able to use several software applications without assistance or felt they could successfully teach others these skills, including word processing, spreadsheet, and presentation software as well as the use of search engines to find information on the World Wide Web. After a second year of implementation, students reported a high level of comfort using these and other applications, including multimedia and communication applications (e.g., iMovie and email) and web-based applications that allow students to check their grades and/or complete tests or other assignments, such as Homeroom.com. The most common uses of technology reported by students were word processing, Internet research, and monitoring grades or completing assessments online.

Surveys of teachers at the end of the first year of implementation show that teachers reported a high level of competence with some software applications and less competence with others. Nearly all elementary and secondary teachers responding to the survey reported that they could use word processing software or find information on the World Wide Web using a search engine. Approximately half of all teachers surveyed reported that they sometimes needed help or did not know how to use presentation software to create a presentation, while two-thirds of elementary teachers and nearly 40 percent of secondary teachers reported similar difficulties with using a spreadsheet to enter and calculate numbers. At the end of the Year 1, elementary teachers were slightly less likely to have reported they use technology to enhance teaching and learning than secondary teachers, with 54 percent of elementary teachers and 74 percent of secondary teachers responding that they make a conscious effort or naturally include technology in teaching and learning, integrating it in lessons in effective or powerful ways. The following sections address more fully the ways in which technology is influencing instructional practice.

The use of technology in the classroom by teachers also varies by several key factors, as reported by teachers and students in focus group discussions. Teachers echoed students in saying that they find technology to be applicable in some subjects for certain topics, but not applicable in others. Teachers of English/language arts or social studies were more likely to find routine applications of basic software, such as word processing, while many teachers in math or science found the applicability of technology to be dependent on the use of additional content-specific software or curricular tools. In addition, the personal comfort level and experience with technology of individual teachers affected their use of technology in the classroom, a finding that supports the conclusion of past research that teachers' rating of their preparedness to use technology is linked to the frequency of their classroom use. While interviewees and focus group attendees reported that teachers across the board were embracing the technology initiative with a positive and willing attitude, teachers, principals, and central office administrators alike described a wide range of teacher experience levels and both students and teachers linked the frequency and type of use in classroom activities to individual teachers' comfort and experience levels.

Data obtained from classroom visits provide additional information about the variation in use of technology across classrooms. As noted earlier, we visited 38 classrooms across all four Quaker Valley schools in March 2003. Visits were brief, lasting from a few minutes (if, for example, students were taking a test and there was no instruction to be observed) to 30 minutes. Classrooms were visited once, so data represent a snapshot of the activity going on in a given classroom on the day of the visit and should be interpreted as such. In just over half of the 38 classrooms, students were engaged in an activity using their laptop computer at the time of our visit. Of these, two-thirds involved technology use as an integral part of the lesson or activity for many or all students, while the remaining one-third had students using their computers in an optional or voluntary capacity, for example a student choosing to type notes from a teacher's lecture rather than write them by hand. In over 40 percent of the classrooms, we observed no evidence of technology use by students at the time of our visit. Similar levels of variation were seen in classrooms at each level of schooling.

Changes in Instructional Practice

According to written descriptions of the goals of the DSD project by Quaker Valley central office administrators, several changes to instructional practice were expected to occur as a result of the technology initiative. Two changes foremost in the district's thinking include integration of technology into the curriculum with changed or improved teaching practices that utilize technological opportunities, and changed availability and time for instruction based on more efficient management of duties. Recalling the Theory of Change (see Figure 3), these aspects of instructional practice correspond to the organizational and behavioral changes of instructional staff shown in the middle column of the diagram. The theory hypothesizes that these changes in behavior will result from the implementation of the program and will in turn bring about outcomes for the teachers and administrators themselves as well as students and parents.

In general, teachers and students reported that technology is used primarily as a tool or resource to assist with teaching and learning. Functions previously performed by hand, such as recording student attendance and achievement, taking notes in class, or looking up information in the library, are now often performed on teacher and student laptops. Reports of laptop use focused around these administrative or management tasks, with students and teachers reporting mostly positive views about the availability of the laptops to assist with performing these tasks. In addition, students and teachers saw accessibility of the Internet as a great resource for the purposes of conducting research and monitoring assignments and grades.

Existing surveys of teachers and students provide limited data on the use of nontraditional teaching practices, such as cooperative learning, in the first year of implementation. According to the results of student surveys, at the end of the first year of implementation significant percentages of secondary students reported they frequently interacted with peers to learn with and from each other in the class where technology is used the most. Two-thirds of middle school students reported that peer-based interaction and learning happened most or all of the time in the chosen class, while high school students reported lower frequencies of peer-based learning, with anywhere from 20 to 50 percent of high school students reporting similar interactions.[5] Survey questions also asked students whether they take an active role in learning, where their teacher acts more like a coach, in the class where technology is used the most. While responses of middle school students indicated this was likely to happen some or most of the time, between one-third and one-half of high school students responded that they did not take an active role in learning in the class with the greatest technology use.

In response to similar questions, approximately half of the teachers who responded to the survey said that they involved students in cooperative rather than competitive learning quite a bit or very much. A similar percentage of teachers responded that they serve as a coach, not lecturer or whole-group discussion leader, with great frequency. Again, these results represent student and teacher perceptions at the end of the first year of

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[5]Survey results provided to RAND were reported as response category percentages by grade without relevant sample sizes.

DSD implementation. Without similar data from years prior to or after the first year of implementation, we are unable to make comparative statements about any possible changes in instructional practice beyond the increased use of technology for administrative or management purposes.

While the data available for this report have limited capacity to make conclusions about instructional practice or track changes in instruction during the DSD initiative, challenges facing the successful integration of technology into instruction were evident when speaking to teachers and district administrators. Qualitative data speak to the degree to which the district's goals for instructional practice as named earlier—curriculum integration through changed teaching practice and increased ability to offer individualized attention to students—were happening successfully by the end of the second year of project implementation. We address these issues in the following two sections.

Integration of Technology into the Curriculum

The integration of technology into the curriculum involves drawing a distinction between utilizing technology as a tool primarily for the sake of using technology, and using technology to support the content or because it provides an appropriate and useful method for completing tasks, such as presenting material or searching for relevant information (Keane et al., 2003; Angeli, 2003). Instead of planning lessons around technology use, it requires teachers to plan lessons around content matter while finding or recognizing appropriate technological applications for that content. As Angeli (2003) describes, "If technology is to be viewed as an add-on in the learning environment that is pursued for the sake of the technology gadgets alone then it will not change education. On the other hand, if technology is utilized as a cognitive tool that has an added value in certain instructional situations then it will manage to become part of the microcosm of the classroom and enhance students' thinking and learning processes" (p. 1).

Teachers at Quaker Valley described the process of recognizing how to use technology as a cognitive tool, and planning lessons that incorporate appropriate technology use, as challenging, time-consuming, and requiring a new set of skills, knowledge, and experience base. This finding is consistent with prior research on successful implementation of technology initiatives. While some examples of successful curricular integration were happening in the district, teachers, principals, and district administrators spoke of several interrelated factors that may be hindering the successful integration of technology into the instructional practice of the majority of teachers. Several respondents explained that although curriculum integration is a clear goal of the DSD project, the district had not explicitly worked to bring about curriculum integration in a systematic, district-wide manner. At the district level, work had not begun to rewrite syllabi and/or other curricular documents to link technology use to existing content standards or make available content-specific software. Results of existing surveys of teachers reveal that at the end of the first year of implementation, approximately two-thirds of elementary teachers and half of secondary teachers reported that they did not use subject-specific software in teaching and learning. At the end of the second year of implementation, many administrators we spoke with were not aware of a clear plan at the district level to formally integrate technology into district curriculum. While a Digital School District Think Tank was created to discuss the DSD initiative, including matters of curricular integration, there was not a clear sense of how these monthly meetings impacted teachers' work.

Teachers as a whole felt that the responsibility for finding appropriate ways to incorporate technology into their classroom practice was placed primarily on teachers themselves. One middle school teacher remarked that while all teachers used technology for management purposes, curricular integration depended on the individual teacher's ability, aptitude, and time. Though most recognized the existence of a technology teacher in each school to provide training to teachers on basic skills and provide guidance when asked about effective ways to incorporate technology into lessons, the team of technology teachers was not seen as able to meet the needs of all teachers regarding appropriate technology use in instruction. In fact, the three district technology teachers agreed that they were unable to spend a sufficient amount of time helping teachers with matters of curricular integration. Instead, the technology teachers reported they spent half or more of their time fixing broken laptops or dealing with student problems, leaving them little time to support teachers.

In addition, teachers and administrators discussed the lack of formal professional development related to appropriate infusion of technology into instruction. Quaker Valley's system of professional development provides daily professional development time for teachers throughout the school year, as well as additional in-service days. Though much professional development time was used for technology-based training, teachers reported that the majority of the time thus far had focused on procedural issues, for example training teachers on basic skills related to using software or district administrative tools. Training sessions focusing on how to integrate technology into certain content areas or plan lessons with appropriate technology applications were informal, voluntary, and often planned by teachers and presented to a small group of colleagues. According to district members, the district had not yet provided a formal set of trainings on curricular integration, with required attendance for all teachers, and instead relied on a "snowball approach" for spreading such ideas and knowledge to teachers, where one or more teachers share new ideas for appropriate technology use informally with a small group of colleagues who then pass on the information to others. In focus group conversations, several teachers asked for more explicit training and materials to help them integrate technology into the curriculum.

Finally, the fact that teachers were not formally held accountable for the use of technology in their classroom practices may have impacted curricular integration. Formal accountability for teacher behavior in this context refers to mechanisms, such as including use of technology in formal teacher evaluations or providing incentives or consequences for use/non-use of technology, to ensure that teachers participate in the initiative in ways or to the degree specified by the district.

When asked about district expectations for technology use, teachers, principals, and district administrators reported that teachers were required to perform many administrative tasks using technology, and principals noted that there was an expectation that teachers could not abstain from technology use altogether. Overall, teachers seemed receptive to learning and trying new things related to the available technology regardless of their individual aptitude. However, there was not a formal accountability system in place making district expectations clear to teachers and holding teachers responsible for the frequency and manner in which they used the computers and other technology in their classrooms, possibly leading to less effort to integrate technology into instruction by some teachers. As discussed earlier, both students and teachers reported that technology use in the classroom was in some ways dependent on individual teacher experience levels. Therefore, without a formal accountability mechanism related to technology use, coupled with appropriate training, teachers with less experience or comfort using technology may have resisted trying to incorporate technology into their classroom practice as more than a management tool.

Use of Teacher Time for Instructional vs. Management Tasks

The second district goal surrounding changes to instructional practice as a result of the DSD initiative relates to teachers and principals gaining more time for instruction because of more efficient management of other duties as a result of enhanced technology. Here, as illustrated in the Theory of Change, the district is hypothesizing that advancements in technology will lead to maximized learning opportunities, thereby working to increase student achievement and other outcomes. In particular, it was thought that the advanced technology would allow teachers to more efficiently manage instruction, communication, and administrative tasks. With less time spent on clerical or management tasks, teachers would have more time to plan and deliver individualized instruction and assessments for students, collaborate with peers and discuss student progress, and communicate with students and parents. Similarly, less time spent on management duties would provide principals with more time for classroom visits and interaction with teachers regarding instruction.

Two years into implementation, experience has indicated these goals may represent a more long-term vision of how enhanced technology may impact the way teachers spend their time and manage their various responsibilities. Data collected at the end of the second year of DSD implementation show that at this time many teachers are in fact spending more time on clerical and management tasks and instructional planning, so do not have additional time to dedicate to individualized attention for students or collaboration with peers, as was hypothesized.

First, several teachers reported an increase in clerical responsibilities, such as tracking professional development credits. In fact, the Digital School District Framework for Action[6] states that teachers will be both empowered and more accountable for student grade reports, home/school communication, and information management (p. 19). With greater responsibility placed on teachers to provide principals with organized student data, principals in turn may have more time available to analyze data, identify trends, and plan appropriate interventions. While some teachers felt that the technology allowed them to manage their administrative duties more efficiently, others did not find that the technology created a savings of time when performing these tasks. In addition, many teachers discussed spending a great deal of time helping students with technical problems related to their laptop computers, which sometimes interfered with lessons or other instructional time.

More important, teachers overwhelmingly agreed that instructional planning to incorporate technology into lessons was very time-consuming. As described earlier, teachers explained that the responsibility for finding

[6]See Parent/Student Handbook, 2002–2003

appropriate applications of technology in their content area and developing lessons that utilized the technology fell primarily on teachers to do in their own time, with little systematic or formal support from the district. This often meant a large time commitment for teachers. One middle school teacher explained that since students had discovered how to disable the district's Internet content filtering software, it was necessary for him to check each and every link on a Web site before including it in a lesson, causing him to sometimes spend a great amount of time to ensure that the information on or linked to any site in his lesson was safe and appropriate for his students. In many ways, the teachers we spoke to who made the greatest efforts to integrate technology into their lessons had the least time left for individualized work with students or communication with peers and parents. As a high school teacher remarked, "It doesn't save me time. This is my hardest year of the nine years I've been teaching. The end result is great, but it takes so much time." In effect, increased use of technology in instruction led to decreased time for other instruction-related work for many teachers.

Teachers also described spending more time on instructional planning because of the need to plan two lessons—one with activities using the laptop computers and another with non-technology-based activities—to be prepared for students with missing or broken laptops. This seemed to be especially problematic at the middle school level, where teachers reported high percentages of students without laptops in class on a given day due to laptops being broken, sent away for repair, or left at home by students. For example, several 6^{th} grade teachers reported in focus group conversations that over 50 percent of students in the grade did not have their laptop available in class on a day where students were specifically working on a technology-based project and had knowledge ahead of time that their laptops would be needed. For this reason, teachers reported often including optional technology-based activities in lessons, but rarely made laptop use a fundamental part of instruction because of the high percentage of students without working laptops at any given time. Again, these examples serve to describe the large time commitment required of teachers trying to incorporate the laptops into their classroom practice. Therefore, many teachers reported that they did not have an increase in time for collaboration and individualized student instruction.

Finally, there was some evidence of teachers' ability to more easily target assessments to individual students' needs with the introduction of Homeroom.com into Quaker Valley's schools. The program, a product of The Princeton Review, is an online assessment and benchmarking tool for tracking student performance. The site contains questions tied to state standards and student textbooks in math, reading, and language arts, allowing teachers to create practice activities and assessments based on chosen content matter which students then complete online. The site provides teachers with immediate feedback reports detailing performance by student and/or class, allowing teachers to find specific content areas or standards where students need additional instruction. At the time of our visit, Homeroom.com had only recently been introduced into Quaker Valley schools, and teachers discussed early examples of how they were able to utilize the information provided by Homeroom.com to deliver customized assessment or instruction to students. The advantages of this type of web-based application were just starting to be seen in Quaker Valley, and teachers and principals shared optimism about the potential for programs like Homeroom.com to allow more individualized attention for students.

Use of District-Based Home Connection

Overall, we found that use of the district-provided home Internet connection was inconsistent among parents and students. Results from a survey[7] mailed to the parents of all students in grades 3–12 in January 2003 show that 85 percent of homes represented by survey respondents had Internet access prior to the school district providing a connection. Many parents and students indicated in focus group conversations that they frequently relied on their personal home connection for Internet access.

In general, parents indicated that they did not make frequent use of the home connection to access information about their students or the school or district as a whole. Survey results reveal that just over 40 percent of parents had not used the home connection for these purposes during the school year, with another 36 percent of parents reporting using the connection between one and five times. While a small number of parents we spoke to reported great benefits of being able to use the district-provided connection to access student grades and other information, many others chose not to use the connection for a variety of reasons. As stated above, many opted to use their personal home Internet connections. In addition, several parents had not obtained the necessary access codes or passwords from the district. Though they were aware that the codes were needed and available from the district, they chose not to obtain them. Others reported needing training from the district about how to use the

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[7]Survey administered by research team from Carnegie Mellon University. See "Data Sources" on page 6 for a description of available survey data.

home connection. Finally, parents had strong negative comments about the numerous technical problems with the home connection and lack of timely and appropriate technical assistance from the district and/or service provider, preventing effective use of the home connection.

Student use of the home connection varied widely by grade level, teacher, and individual student preference. While some students we spoke to reported taking their laptops home and connecting to the Internet via the district connection daily or several times per week, others reported rarely taking the laptops home and/or using the home connection. Similar to parents, students mentioned having frequent technical problems with the home connection, causing many to opt to use personal home Internet connections. Some teachers mentioned that because of the unreliability of the home connections, they could not plan lessons or homework activities that required students to have access to the school network from home.

In general, greatest use of the home connection was reported at the high school level. Parents, teachers, and students themselves reported that for elementary and middle school students, use of the laptop computers at home, including the use of the home Internet connection, was often not for educational purposes. Instead, student use at home was focused on activities such as games, email, and personal use of the Internet. A small number of parents described some personal use by younger students as inappropriate, such as visiting adult Web sites or sending vulgar email. Even students who did not deliberately seek out inappropriate material sometimes received it via email from other students. These incidents caused concerns among some parents about the mechanisms in place to safeguard the home connection.

Partly in response to this problem, as well as to reduce cost, the district is planning revisions to the home Internet connection provision for the 2003–2004 school year. As of late September, there are no home Internet connections provided by the district, but the district's goal is to have some form of connection in place in early October. A design goal for the new mechanism is to ensure that student access will be forced through the same Internet content filter used in the schools. Under one plan currently under exploration, families that already have Internet connections at home at their own cost would be provided with a wireless routing device for the students to use. Under this plan, special provisions would be made for low-income families that do not have Internet connections only if there is a curricular need for home access, such as taking an online distance learning course. Otherwise, students without home Internet connections would be expected to use the public access connections in the public library or community center.

Management and Technical Support Mechanisms and Policies

Data collected from interviews and focus group discussions revealed several overarching themes about the management and technical support mechanisms and policies surrounding the implementation of the DSD initiative. From the perspectives of parents, teachers, principals, and central office administrators at the end of the second year of project implementation, several factors were seen as potential challenges or areas of concern related to the policies and support mechanisms guiding the DSD implementation.

First, some respondents questioned the decisions made by the school board and/or district administrators surrounding the specific nature of the DSD initiative. In the opinions of some, decisions may have been made based on an ideal conception of how a Digital School District might operate, without considering the practical implications resulting from the decision. For example, several parents and teachers questioned the decision to provide email access to all students in grades 3–12. With many students using the email capabilities in inappropriate ways, parents and teachers noted that as a result of this decision, an additional burden was placed on them to monitor student behavior. These same respondents questioned the potential benefits of this technology for students, particularly in elementary and middle school. Members of the district technology staff further questioned this and other decisions, adding that in some cases problems and confusion related to certain aspects of the DSD initiative could have been avoided had the district consulted its technology experts and included them in district planning and decisionmaking. Teachers also expressed the desire for district leaders to consult with teachers about what is and is not working for future planning and decisionmaking.

Along similar lines, many respondents saw the number of district technology experts as inadequate to meet the district's needs, supporting the conclusion of past research that sufficient technical support is a key component of an effective technology program. Team members reported being overwhelmed, frustrated, and burned out by the long hours spent fixing student computers and dealing with other technical problems. Problems with computers and the home connection, maintenance of the technology infrastructure, and frequent additions of new software or management tools left the technology team in a constant "firefighting" mode and created frustration for both the technology experts trying to provide needed support and the parents, teachers, and students in need of assistance. In addition, as discussed earlier, the district's technology teachers also spent a majority of their time fixing problems with computers, allowing them insufficient time to work with teachers on matters related to curriculum and instruction.

More specifically, according to district records, the Apple iBook computers provided to the students required significant numbers of repairs in the first two years of use. During the first year of use, student laptops were sent back to Apple for a total of 724 repairs due to computers breaking or malfunctioning. In addition, at the end of the first year of the program, every computer was sent back to Apple for maintenance related to a set of three commonly occurring problems. In the second year, student computers had to be sent back to Apple for a total of 2,109 repairs. Each of these repairs took an average of 10 days. Therefore, during the 2002–03 school year, the average student computer was away for repair for an estimated 13.5 days. This figure does not include additional downtime for in-house repairs, or for time the students kept computers that were broken before turning them in for repair.

Repairs were disproportionately high at the middle school level. There the average computer was sent to Apple 2.2 times, while at both the elementary and high schools the average was closer to 1 time per computer (0.9 at the elementary schools, and 1.1 at the high school). One possible explanation for the difference in repair rates by level of schooling is that elementary school children may have taken the computers home relatively infrequently, while middle school students likely took the computers home more frequently. As compared to high school students, middle school students may have lacked the maturity to properly care for their laptops, particularly when they were in their care outside the classroom setting.

A third concern voiced by many of the teachers regarded software availability and use. In particular, teachers spoke of several changes to the administrative or management software required for tasks such as grade reporting. Teachers described small groups of colleagues receiving training in a certain application, only to learn that another program subsequently had been adopted. At the time of our visit it seemed that software selection for these purposes had just recently become more stable, and while teachers spoke positively about current applications such as PowerSchool and Homeroom.com they also wondered if future changes would occur.

Further, teachers were not satisfied with district policy requiring an extensive approval process before using other content-based software packages to support existing curriculum. The approval process was instituted to ensure that the software was compatible with the other installed software, and that the use would comply with copyright restrictions and licensing terms. For example, middle school teachers described choosing a particular reading series in part because of the accompanying software components, however, they were ultimately unable to use the software with student computers. Therefore, the software went unused while teachers were left to find other ways to incorporate technology into their instruction.

Finally, several questions emerged from parents, teachers, and students about the appropriateness of the iBook laptop computers to be used as the DSD initiative envisioned. As described above, the district experienced a high rate of breakages with the student laptops. Many questioned whether the iBooks were sturdy enough to hold up to the normal, everyday classroom and home conditions they experienced with preadolescent and teenage students. As one middle school teacher remarked, "I don't think the equipment was designed for the purpose we are using it for. It is not meant to be shoved in a locker, or taken to the cafeteria or soccer practice."

In the next section we consider the perceived impact of the DSD initiative on students, teachers, and administrators as described in interviews and focus group discussions in March 2003.

FINDINGS REGARDING IMPACT OF THE DSD INITIATIVE

Impact on Students

Parents, teachers, and students saw the DSD initiative as having several benefits for students. First, students at all grade levels benefited from increased awareness of and competence with various types of technology. The availability of laptop computers and Internet access both in school and at home provided students with more than ample opportunity to gain experience with software and web-based applications. Students reported experimenting with new applications and teaching themselves new skills with their computers, while parents and teachers reported that they were often surprised by the high level of technology-based skills acquired by students in short periods of time. One elementary teacher described the "amazing results in student work" seen with students utilizing their laptop computers to complete assignments. Many respondents also felt that this experience and level of competence with current technology would place Quaker Valley students at a distinct advantage in future educational and employment situations.

The availability of the laptops and Internet connections and their use during school and for home assignments worked to increase many students' motivation and engagement with school activities, as was suggested by previous research. Teachers at all levels reported that students were excited by lessons and activities using the technology and were more likely to become engaged in writing or research activities than before the DSD initiative. Several parents also described their children as excited and enthusiastic about more aspects of school. Interestingly, several students seemed more indifferent about the laptop computers at the end of the second year of implementation than parents or teachers, explaining that the "coolness" factor of having their own laptop had worn off to some degree. Other students echoed the feelings of parents and teachers by expressing excitement about the technology available to them.

Other positive effects described by teachers included students' improved communication skills, both with teachers and with peers. Some teachers described students as being more confident and more willing to work with and teach other students when using the computers. Additionally, the introduction of grade and assessment applications such as PowerSchool and Homeroom.com gave students the ability to regularly monitor their own progress. Teachers reported that some students were taking more responsibility for their own learning and for meeting all class requirements by utilizing these programs.

While students seemed to benefit from the DSD initiative in many ways, some negative consequences of the technology initiative were also seen by teachers, parents, and by students themselves. First, some students used the technology in inappropriate ways, including tampering with the district's network security measures and Internet content filtering software, plagiarizing text, playing games and using email at inappropriate times, and harassing students and teachers with email. Mostly, the inappropriate use was limited to minor offenses, such as playing games, searching the Internet, or sending emails during class. As teachers described, students who previously passed notes on paper or doodled in a notebook now used their computers for similar misbehavior or daydreaming. More serious offenses, though committed by a small minority of students, nonetheless posed serious challenges to administrators. District leaders we spoke with were currently considering how to provide students with instruction related to the ethical and responsible use of the technology.

Some teachers and administrators voiced concern that students were learning the wrong lesson about caring for an expensive piece of machinery such as a laptop, since students were able to mistreat and then turn in broken computers to be fixed without facing negative consequences or receiving additional instruction about proper care. Teachers and principals also spoke of social difficulties facing a small group of students who became attached to their computers and avoided other social interaction with peers. In particular, some elementary and middle school students relied on computer games as their primary social outlet during free time in and after school. Finally, some students reported that the computers caused them to be less creative when completing school assignments. One middle school student remarked that every teacher now did projects using PowerPoint, so while he previously gave considerable thought to how to use posterboard, bright colors, or other artistic or creative methods to present his work, he now simply had to type a PowerPoint presentation and add a few pictures from the Internet or interesting graphics to satisfy the requirements for the assignment.

Impact on Teachers

Teacher responses about the impact of the DSD initiative on their professional activities revealed both positive and negative perspectives about the effects of the initiative. Most teachers described the technology advancements brought on by the DSD project as a great resource for teachers. As mentioned earlier, the recent implementation of instructional and assessment applications provided teachers with immediate feedback about student performance and gave teachers new resources for planning individualized web-based instruction and assessment for students when remediation was needed. Teachers also described the technology as an enrichment tool, allowing them to add new sources of information, examples, or activities to certain lessons. Many teachers had positive opinions about the increased capacity provided by the advanced technology for communication with students, parents, other teachers, and their principal. However, many remarked that increased capacity did not always result in increased use; for example, teachers reported that a large percentage of parents still preferred to communicate by phone or receive paper copies of all school or class announcements.

While some teachers praised the computers and Internet access as allowing them to manage their professional responsibilities more efficiently, the majority of teachers we spoke to claimed to have an expanded workload as a result of the DSD initiative. As described in detail earlier, teachers had some additional clerical responsibilities and in general spent considerable time planning instruction to utilize the computer as well as dealing with technical problems. Teachers, particularly at the middle school level, also had to spend more time monitoring student behavior due to inappropriate uses by students, as described above. Finally, a small group of teachers felt that the technology initiative as implemented impeded or distracted from their instructional time. One middle school teacher remarked, "It was supposed to help kids learn, to be a tool to drive education. Instead it's driving us."

Impact on Principals

Overall, Quaker Valley's principals reported positive effects of the DSD initiative on their ability to perform their job as principal. In particular, principals described the technology advancements as assisting them with their role as instructional leader. Similar to teachers, principals praised applications like Homeroom.com for their ability to provide immediate feedback on student performance and target additional instructional activities and assessments for students needing assistance. Principals also appreciated resources, like Homeroom.com, that provided curriculum materials aligned with state standards and assessments. However, one principal remarked that it was necessary for principals to be up-to-date on district software and aware of future technology plans to best serve as a model for teachers and influence classroom instruction. Principals also felt the technology positively impacted their capacity to communicate with parents, faculty members, and district leaders, which in turn allowed them to perform these and other responsibilities more efficiently.

Principals also voiced questions and concerns about various aspects of the DSD implementation and their role as principal. Because both student and teacher characteristics and appropriate technology applications varied by grade and experience level, principals discussed the need to consider the DSD implementation strategy independently at each school building. Principals also described the challenges they faced and considerable time spent dealing with technology-based misbehavior by students, causing them to work to develop a standard set of appropriate disciplinary actions. Finally, while principals agreed that teachers were generally receptive to the technology initiative, the lack of formal accountability mechanisms to evaluate the use of technology by teachers, as described earlier, impacted to some degree principals' ability to monitor technology use in their building. For example, principals noted that while teachers are encouraged to utilize technology in their classroom practices, the absence of district requirements for use or consequences for nonuse limited principals' ability to impact the degree of curricular integration happening in their building.

PLANS FOR FUTURE EVALUATION OF THE DIGITAL SCHOOL DISTRICT INITIATIVE

We now move to a discussion of plans for a future evaluation of the Digital School District initiative. We begin by observing that the specific goals of the evaluation will vary for the potential audiences of the evaluation, but also identify some elements that are common among the goals of all of these audiences. We then revisit the Theory of Change and develop a set of questions to consider related to future implementation and evaluation of the DSD initiative. These items then lead to a plan for a broader and more comprehensive measurement of effects of the DSD initiative, including the types of data that can be collected and some analyses that can be performed. This is followed by discussion of the question of attribution, that is, the ability to conclusively show that any observed effects are a result of the DSD initiative as opposed to other factors. The section concludes with discussion of several factors inherent to the Quaker Valley initiative that limit the potential strength of any future evaluation.

IDENTIFYING THE GOALS OF FUTURE EVALUATION

In planning for future evaluation of the DSD initiative, it is important to consider the goals of the evaluation, which are not necessarily the same for all of the various parties who may be interested in the evaluation. For example, the district and the project's funding sources may be interested in evaluation results to determine whether the DSD investment has paid off and to decide whether the initiative should be continued. Key stakeholders in the district may be interested in learning what aspects of implementation are working well and what aspects could be improved. Other districts may be interested in the Quaker Valley experience because they are considering similar interventions. For example, they may be interested in the overall value of the intervention in improving outcomes, or they may be interested in identifying key enablers and barriers to successful implementation, and what characteristics of the Quaker Valley School District may have affected success. Policymakers might also be interested in an evaluation of the Quaker Valley initiative to help guide decisions about whether to foster similar initiatives on a wider scale, and if so, how policies should be informed by the Quaker Valley experience. Finally, the research community may be looking for lessons and findings from this project that might further the understanding of the use of technology in education.

Each of these evaluation goals can lead to a variety of research questions to be examined in the evaluation. Two common elements among the evaluation goals described above include: gaining a detailed understanding of the nature of the initiative's implementation, including various strategies chosen by the district and the relative effectiveness of such strategies in achieving desired changes in behavior and outcomes; and determining whether observed effects can be unequivocally attributed to the DSD intervention, as opposed to other causes. We begin to address these elements by using the Theory of Change as a framework for identifying and organizing the key features of implementation and expected outcomes to be considered in a comprehensive future evaluation.

REVISITING THE THEORY OF CHANGE

In planning for further evaluation, it is important to consider the nature of the initiative's implementation and the expected changes in behavior and other outcomes predicted by the district. This step should be taken to assure that an evaluation is able to make reliable and valid statements about the outcomes and processes of most interest to the parties involved. For this to happen, there must be a clearly stated, well-defined idea of what is expected to occur as a result of the intervention and how these results will be brought about, in effect identifying what must be measured to successfully carry out an evaluation.

To address this task we first revisit the Theory of Change presented earlier in this report. Recall, the Theory of Change shows the hypothesized causal links between the DSD initiative and outcomes for teachers, administrators, students, parents, and community members. The findings reported in the previous section speak to the implementation of the DSD initiative in its first two years, and early impacts seen on various members of the district. Building on these findings and ideas from relevant research on sustaining educational technology programs as described in detail in the review of literature presented earlier, we have added some detail to the Theory of Change diagram—five key aspects of implementation that are critical to the success of a technology initiative like Quaker Valley's (see Figure 4). Specifically, implementation of an educational technology program like the DSD must include:

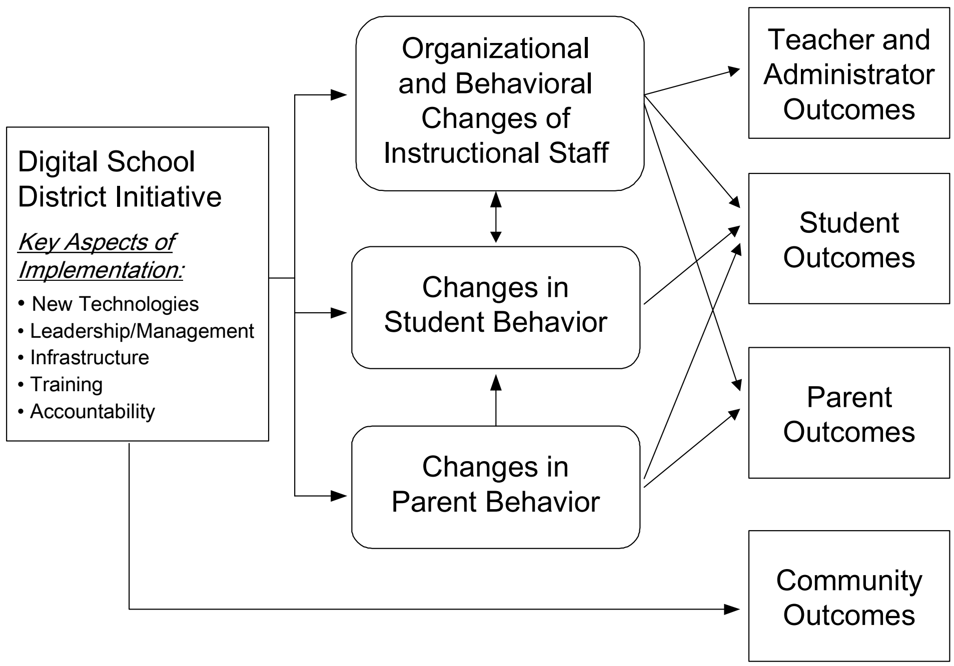

Figure 4—Digital School District Theory of Change: Key Aspects of Implementation

- Successful dissemination of the new technologies. This includes distribution and installation of all of the needed hardware, software, and documentation, in a timely manner.
- Effective leadership and management of all aspects of the program. This includes providing a clear vision for the program, supplying staff with the support needed to implement the vision, and openness to feedback from stakeholders.
- Sufficient infrastructure. This includes providing adequate technology resources as well as sufficient technical support staff.
- Appropriate and sufficient training for all parties. This includes not only training on the mechanics of using the technology, but also professional development on curricular integration and lesson planning.

- Mechanisms to hold participants accountable for implementation of new technologies, given appropriate training. This includes incentives for use and consequences for nonuse of the technology, and mandates for instructional staff to participate in key professional development activities.

The district should review and refine this Theory of Change to be sure it accurately describes the district's theory about the processes through which the technology initiative will impact the district and its members. A future evaluation must then be designed to systematically investigate the various pathways and outcomes described in the model. It is necessary to monitor implementation as well as behavior changes and expected outcomes in order to gain a complete understanding of the program. If the key aspects of implementation are successful, the changes in behavior shown in the middle column of the diagram are more likely to occur, thus improving the likelihood that the expected outcomes will be achieved.

Learning about each of these characteristics of the DSD implementation is central to determining the overall impact of the initiative; therefore measures of these characteristics should be considered important intermediate outcomes in a future evaluation. Furthermore, they provide feedback that enables midcourse changes and improvements to implementation. While this feedback loop is implicit in the district's current plans and actions, it may be worthwhile to make it a more explicit part of the DSD program.

In particular, the study should monitor the key aspects of implementation listed above. Within each category, the district's implementation plan should be identified and assessed as to whether it is working. Barriers and enablers that may be impacting the success of the district within a particular category should be identified. Furthermore, areas of relative strength or concern should be identified and methods for addressing areas of concern should be explored. In evaluating these points, the district should consider the perceptions of students, teachers, administrators, and parents as described in this report, as well as other measures of implementation collected as part of the evaluation activities.

RESEARCH QUESTIONS

Assuming the Theory of Change pictured in Figure 4 matches the district's goals and hypothesized mechanisms for bringing about change, the above discussion leads to the development of a general set of research questions for a future evaluative study of the DSD initiative. The following list contains suggested broad research questions, along with some illustrative examples of more detailed questions related to each broad question:

1. **What have been the changes in district institutional practices and support structures as a result of the DSD initiative?**

   For example, has the organization or responsibilities of district personnel changed to manage activities related to the technology initiative? Have district hiring practices been altered to reflect technological skills? How must classroom facilities change to support student laptop use? For example, are student desks large enough, and are they ergonomically correct to avoid repetitive strain injury and related physical hazards?

2. **In what ways are district and community members utilizing the new technology?**

   For example, to what degree do teachers report using the technology as a management tool? As an instructional tool? What percentage of students and parents in the district report monitoring student performance on a regular basis? Do community members not associated with the district report using the publicly available technology? How often, and in what ways?

3. **What has been the impact of the technology on teachers' instructional and management practices? What impact has the technology had on principals' actions as instructional leaders?**

   For example, to what degree are teachers spending more or less time on administrative or management tasks? How often do teachers report incorporating student laptops as an integral part of classroom activities? In what ways has technology changed the daily activities of principals? Has teacher communication with peers related to student progress and instructional methods changed in frequency or content as a result of the initiative?

4. **What impact has the technology had on student academic and social outcomes?**

   For example, do students report changes in engagement or participation in school activities as a result of the technology program? Were subgroups of the student population differentially affected by the program? Do effects of the laptop program vary across grade levels? What is the impact on opportunities for students to take diverse or advanced courses?

5. **What facilitates effective use of the technology? What hinders effective use?**

   For example, to what degree has professional development or other trainings for teachers increased teacher perceptions of their competence with technology? What do teachers report as the factors most influencing their decision to utilize technology in instruction or other activities? To what degree have technical problems with student laptops deterred teachers from incorporating laptop use in instruction?

6. **What have been the costs and benefits associated with the DSD initiative?**

   For example, what has been the total cost of the DSD initiative during its implementation? What is the estimated yearly per student cost of the initiative? What percentage of the program's cost came from donations or in-kind contributions?

7. **What are the implications for the implementation and sustainment of similar initiatives in Quaker Valley and in other schools, districts, or states?**

   For example, is Quaker Valley's implementation strategy feasible in a much larger district? What factors might facilitate or constrain the implementation of a similar technology program in a district or school with different characteristics? What alternate implementation strategies may promote similar positive outcomes for larger populations or at reduced cost?

With these research questions in mind, we now suggest a possible strategy for a future evaluation of the DSD initiative, assuming continued implementation.

DATA COLLECTION

The Theory of Change along with the set of research questions provides a roadmap for data collection. In order to systematically examine the Theory of Change, data must be collected about each of the areas of change and pathways shown in the model, as well as general demographic characteristics of the groups of people involved: teachers and administrators, students, parents, and community members. The limited data collection and analyses conducted for this report are a preliminary step in this direction; Table 2 provides a more comprehensive

Table 2

Possible Data Items for Continued Evaluation of DSD Initiative

Data Items	Sources of Data[a]				
	Students	Teachers	Administrators	Parents	Community
Demographic Characteristics					
Student characteristics *(enrollment, ethnicity, socio-economic status, etc.)*	X				
Teacher and administrator characteristics *(certification, years of experience, etc.)*		X	X		
Parent characteristics *(prior experience with technology, occupation, etc.)*				X	
Community member characteristics *(age, ethnicity, socioeconomic status, etc.)*					X
Implementation Measures					
Successful dissemination of the new technologies *(implementation progress, etc.)*	X	X	X	X	X
Effective leadership and management of program *(focus on curricular integration, sufficient resources and staffing, openness to input from stakeholders, etc.)*		X	X	X	
Sufficient infrastructure *(adequate hardware resources and technical staff, etc.)*	X	X	X	X	X
Appropriate and sufficient training *(professional development on curricular integration and lesson planning, etc.)*		X	X	X	X
Mechanisms for accountability *(incentives for use and consequences for nonuse of technology, mandatory participation in professional development, etc.)*		X	X		
Outcome Measures					
Technology-based outcomes *(frequency of laptop use, accessibility of distance learning courses, kinds of assignments, use of online resources, etc.)*	X	X	X	X	X
Organizational/behavioral changes in instructional staff *(time spent on administrative tasks vs. lesson planning vs. instruction, instructional methods used, instructional tailoring, interactions among principals, teachers, and students, etc.)*	X	X	X	X	

[a]Multiple methods of data collection are useful for gathering data for cells in this table, such as: public records, district records, surveys, interviews, focus groups, classroom observations, etc.

Table 2—*Continued*

Data Items	Students	Teachers	Administrators	Parents	Community
Outcome Measures—*Continued*					
Changes in student behavior *(participation in challenging courses, attendance and graduation rates, disciplinary problems, etc.)*	X	X	X	X	
Changes in parent behavior *(communication with faculty, monitoring of child's progress, etc.)*	X	X	X	X	
Teacher and administrator outcomes *(use and competency with technology, productivity, job satisfaction, etc.)*		X	X		
Student outcomes *(student achievement on PSSA and other exams, motivation and engagement, use and competency with technology, communication skills, etc.)*	X	X	X	X	
Parent outcomes *(use and competency with technology, etc.)*				X	
Community outcomes *(education opportunities, use and competency with technology, etc.)*					X

listing of each category of data along with some example measures in each category, and indicates the potential sources of the data.

To illustrate, let us consider the box in the Theory of Change titled "Organizational and Behavioral Changes of Instructional Staff," along with the corresponding line in Table 2. Research Question 3 contains some questions addressing this expected behavioral change, regarding instructional practices, the amount of time teachers spend on administrative vs. instructional tasks, and how much they incorporate laptop use into classroom activities. Therefore these topics are listed in the table as example measures for gathering evidence about the expected behavioral changes. The table indicates that this data might be obtained from students, teachers, administrators, and parents. Some examples of how this data might be collected are: interviews, focus groups, surveys, classroom observations, or having teachers keep logs of their activities and the amount of time spent on them over the course of a few weeks.

ANALYSIS

In order to describe change over time, these data items must be collected more than once. Ideally, the initial baseline measures would have been collected before the DSD initiative began and subsequent measures would be collected after the program has taken effect. For some of the measures, such as student achievement on the PSSA exams, baseline and post-implementation data do exist. As another example, certain items from the series of annual teacher and student surveys may provide useful baseline or early-implementation measures from the first administration of the survey, and responses from subsequent surveys could be analyzed for changes over time.[8] Unfortunately, baseline data may not exist for other measures. One remedy might be to collect the data immediately to be used as the baseline, although this has the unavoidable disadvantage of precluding detection of any changes that occurred prior to the time of the baseline data collection.

As an example of an analysis that might be done with a time series of achievement data, we conducted some preliminary explorations of PSSA math and reading scaled scores for five years through 2001–2002, the latest date for which scaled scores were available. Any increases in these achievement outcomes in 2001–2002 or subsequent years would be consistent with positive effects of the program. However, other factors could also affect the achievement measures over time. For example, the difficulty of the PSSA exam may change across years, or scores might change due to increased instructional emphasis on state standards. The next paragraph describes one way to try to account for these factors, and the following section provides a more detailed discussion of external factors and methods for addressing them.

Comparison to the scores of other students is one way to remove the effects of external factors that may be impacting PSSA scores. To do this, we subtracted the statewide PSSA averages from the mean scaled scores for Quaker Valley schools, thus examining trends in the difference between Quaker Valley schools' performance and statewide performance. As expected, across all years the difference between Quaker Valley and the state is consistently positive, because Quaker Valley is high achieving relative to the state. However in the years for which data were available, there was no clear trend from pre- to post-implementation of the DSD

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[8]As noted above in "Available Data," the district has already collected two years of teacher and student survey data, although RAND researchers had access to only a summary of the survey results from the first administration.

initiative. This is not necessarily evidence of no effect of the program because these scores are only distantly related to the intervention, and the effect of the program might only occur after it has been in place for a longer period of time. On the other hand, if this analysis is repeated in future years and a very strong trend is found, it might be seen as an indication that the initiative is having a positive effect.

In conducting analyses, if the expected effects are not seen, or they have been uneven among schools or classrooms, the next step is to investigate the underlying causes. If, however, the expected effects are found, caution is warranted before drawing the conclusion that the DSD initiative can be credited. This is especially true on those measures that are not directly related to technology availability and use, because there may be other external factors that could plausibly have caused the effects. The next section discusses the very challenging problem of how to design the evaluation so that any observed effects can be convincingly attributed to the program.

INTERPRETING EFFECTS

A key challenge in evaluation is to support the claim that any observed changes or improvements are the result of the program's implementation and not other factors. In general, this requires comparing the results of participants in the program with a comparison group that does not participate. This enables the evaluation to examine whether the outcomes are reliably different between these two groups as a result of the program. Because individuals cannot both participate and not participate in the program, the challenge is to find or create experimental and control groups where, in the absence of the program, the expected outcomes for the two groups would have been identical. We discuss three strategies that can be used to identify or create such groups: randomization, pre/post analysis of data describing the study population, and matched comparison districts. While not all of these strategies are applicable to Quaker Valley's implementation, they are mentioned here because they might be relevant in designing evaluations of other programs.

Randomization. Randomization is one of the best methods for creating the experimental groups required for evaluation. Individuals are randomly assigned to either participate in the program or not; thus, except for random variation in outcomes, the outcomes are expected to be the same for both groups. Randomization is not an option for the overall evaluation of the DSD initiative as it is currently implemented.

Pre/post analysis of data describing the study population. An alternative to randomization is a pre/post analysis. In this analysis, outcomes for individuals from a period prior to implementation of the program (the pre period) are compared to outcomes for individuals who participate in the program (the post period). Data from the pre period, describing the existing conditions prior to implementation of the program, are the baseline data discussed earlier. These data include not only pre-program measures of the outcomes the program is expected to affect, but also other variables that potentially are associated with these outcomes. For example, in the DSD initiative, student achievement, students' and teachers' expertise with computers, attendance rates, and socioeconomic and other demographic aspects of the population are all possible baseline data items. Note, however, that this analysis cannot separate effects of the DSD program from effects caused by other changes in the district that may also occur over the pre/post period.

Matched comparison districts. Another method for creating a group of individuals not participating in the program is to select a sample of school districts not implementing the program that are otherwise similar to Quaker Valley. These comparison districts must be similar with respect to outcome measures and variables that predict outcomes. However, when using this method any differences between Quaker Valley and the comparison district populations that are not the result of the program could be incorrectly attributed to the effects of the program. That is, program effects could be confused with preexisting differences between Quaker Valley and the comparison districts. In an attempt to avoid such confusion, or confounding, baseline data as described above are used to match districts on preprogram measures of the outcomes and characteristics expected to be associated with outcomes. However, even with matching, the effects of other concurrent changes or initiatives in Quaker Valley or the comparison districts will be impossible to separate from impacts of the DSD program itself.

Estimates of program effects can be obtained by comparing outcomes between Quaker Valley and the comparison districts after the program has been implemented. Estimates can also be obtained by comparing pre to post changes within Quaker Valley and the comparison districts. This latter method has the advantage of measuring change, which is often the outcome of interest. Furthermore, comparing changes removes from estimated program effects other variables that create differences between Quaker Valley and the comparison districts but that are not related to the program, such as differences in the populations served by the districts.

In general, having more comparison districts in the set of matching districts enables better analysis. However, this benefit must be balanced with the expense of additional data collection that must be performed in the matching districts. There also may be relatively few districts that match Quaker Valley well within Pennsylvania. Going outside the state for comparison districts would create an additional analytical complexity if the comparison districts do not administer the same assessments as Quaker Valley, not to mention an increase in potentially confounding factors, such as state policy context.

A first pass at identifying comparison districts can be performed using publicly available characteristics such as size, minority enrollment, low-income enrollment, urbanicity, and achievement. After gaining these districts' agreement to participate, the baseline measures must be collected from all of them. Then, in a second phase of matching, the baseline data can be used to verify that the selected districts match Quaker Valley well. Those that don't should be excluded from the set of matching districts. Subsequently, all measures collected at Quaker Valley would also be collected from the set of comparison districts.

Other considerations. There are several additional points to consider in designing the evaluation. First, the study must have internal validity by removing confounding effects and using appropriate statistical methods for the analysis. As mentioned above, confounding effects arise from extraneous variables that differentially affect outcomes between the two groups, and prevent the researcher from concluding that any observed changes are actually a result of the program. In projects of this type, avoiding confounding presents a considerable challenge. It is very difficult to establish that all pre-existing differences between the pre and post periods, or between Quaker Valley and the comparison districts, have been properly measured and accounted for by the statistical analyses, such that the observed differences between groups truly measure program effects rather than differences in unaccounted for characteristics. However, a well-done comparison can give a strong indication that a program effect is likely, especially if one can rule out the existence of likely confounding characteristics.

A second consideration is the difficulty of demonstrating external validity. Unique characteristics of the Quaker Valley School District may hinder the ability to extrapolate any effects that are observed in the DSD program to how similar programs would perform in other districts. This is especially important to policymakers and researchers who may be interested in the generality of Quaker Valley's results.

Finally, it is necessary to consider sample size. Any inference sought in the study needs sample sizes large enough to obtain statistical power; otherwise the statistical tests may not yield significant results. The necessary sample size can be estimated through power calculations that consider the variance in the measure within the population and the estimated size of the program's effect on the measure.

LIMITATIONS INHERENT TO STUDYING QUAKER VALLEY'S INITIATIVE

There are several aspects of Quaker Valley's ongoing implementation of the DSD initiative that do not meet the needs set forth above. First, there are limited baseline data from before the start of the DSD initiative beyond standardized test scores, attendance, demographics, and other general information. As previously noted, math and reading test scores are not ideal outcome measures because they are only distantly related to the intervention and thus changes may be small or take longer to appear. A related problem is that Quaker Valley was already high performing on these exams, leaving less room for improvement and thus reducing the likely size of any changes that could occur as a result of the program. On targeted measures more closely related to expected program effects, no baseline data were collected. For example, one of the goals of the program was to increase educational opportunities for all members of the community,[9] but baseline data were not collected on opportunities that were available to the community before the program was implemented.

Second, there is no comparison group. As in all district-wide initiatives, the DSD program included all students in targeted grades throughout the district, so there is no group within the district that could be used as a comparison group. Without a comparison group, any changes that might be observed cannot be directly attributed to the program as opposed to some other variable. In addition, a set of comparison districts was not identified. Matching would have utilized measures related to expected program effects, using baseline data collected from comparison districts as well as Quaker Valley. Without the baseline data, retrospective selection of comparison schools may not yield a well-matched set; and comparison of pre/post changes between Quaker Valley and matched districts is not possible.

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[9]See "A Framework for Action," Parent/Student Handbook, 2002–2003.

Finally, Quaker Valley is a small district, and consequently has small sample sizes. Estimates based on teachers or classrooms, and to a lesser degree students, will tend to be highly variable and statistical tests will lack power.

These limitations imply that there may be no highly persuasive and feasible design for an evaluation that demonstrates changes in district behaviors and outcomes that can be reliably attributed to the DSD initiative.

CONCLUSIONS AND RECOMMENDATIONS

This report reviewed data describing the implementation and impact of Quaker Valley's Digital School District initiative through the second year of implementation, and provided a conceptual framework and suggested strategies for carrying out further evaluation of a continuation of the DSD program.

Key findings from qualitative analyses related to DSD implementation and impact revealed mixed perceptions of district members regarding the effectiveness and usefulness of the initiative. Data revealed varied and positive uses of the new technologies by teachers, students, and administrators with reported benefits for all members. However, some unintended negative consequences for students and teachers were evident, such as inappropriate use of technology and increased time spent on administrative and instructional planning tasks. In addition, problems with hardware, connections, and a lack of sufficient technical support mechanisms may have hindered successful implementation of the initiative.

Several questions and issues related to the current implementation of the DSD program became clear throughout the course of collecting and analyzing data for this study. Based on prior research and findings from the qualitative analyses reported here, we offer the following recommendations regarding the ongoing implementation of the DSD program:

- Focus professional development on curricular integration of technology. Existing research identifies targeted professional development as a key factor in successful implementation of an educational technology initiative, and teachers and administrators at Quaker Valley clearly identified a need for additional formal training on this topic.
- Provide an accountability mechanism that clearly states the district's expectations for how the technology will be used in instruction, and provides incentives for compliance and consequences for non-compliance with these expectations. Currently, no formal accountability mechanisms have been instituted; as a result of this and other factors, wide variation in technology use was observed across the district.

- Increase the level of support staffing, both for technical support, troubleshooting, and repair issues, as well as for curricular support to assist teachers with the integration of technology into their lessons and instruction. Adequate support is cited in existing research as a key factor in successful implementation of educational technology programs, while results of qualitative analyses reveal an inadequate amount of technical support available in Quaker Valley given the needs of teachers and students and the reported numbers of hardware and software malfunctions.

- Reconsider the current policy of uniformly issuing personal laptops to all students across grades 3–12. The district might consider alternative policies that might differ across age groups, adapting to how students' needs change as they grow older, as well as their ability to responsibly care for fragile and expensive equipment. Reports of how the laptops are being used as well as patterns of equipment failure suggest that younger children may not be getting much benefit from having personal laptops, and middle school children may lack the maturity to care for them outside the classroom.

- Set up formal mechanisms for all stakeholders to provide input to program administrators, establishing a feedback loop that will help refine and improve implementation. Research suggests that partnership with stakeholders is essential to success, yet many of the people we spoke with did not feel their voices were being heard.

- Consider a close accounting and analysis of the costs of the DSD program to facilitate judgments about the program's cost effectiveness relative to other programs or interventions Quaker Valley or other districts could potentially undertake. Costs are a key issue in sustainability, and the conclusion of the DSD grant is an appropriate time to carefully consider appropriate future investments.[10]

This study also provided a conceptual framework and a Theory of Change describing how the DSD program is hypothesized to impact behaviors and outcomes. Based on this Theory of Change, a set of research questions were developed and factors in planning a future, more comprehensive evaluation of the DSD program were discussed. The outcome of this effort is our suggestion that the district focus future evaluation efforts on formative evaluation, following these steps:

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[10]See Levin and McEwan, 2002 for information regarding cost analysis in education.

- Consider the Theory of Change presented in this report, and refine it if necessary to ensure it is an accurate model of the DSD program.
- Use the Theory of Change as a framework for identifying measures to support a systematic investigation of features of implementation, changes in behavior, expected outcomes, and the casual pathways linking each of these areas as shown in Figure 4. Table 2 provides a comprehensive listing of appropriate data categories to address each aspect of the Theory of Change.
- Collect relevant data over time.
- Monitor data for changes in outcomes of interest and explore all possible reasons why effects may or may not be found related to these outcomes.

This type of evaluation will allow the district to monitor what is happening and will provide feedback that can guide refinement and improvement of the DSD program. However, it will not permit the district to make conclusive statements about the program's causal effect on outcomes, due to several limiting factors of the current DSD implementation, including the district-wide nature of the project and the lack of a comparison group; the limited availability of pre-implementation baseline data; and characteristics of the district such as its small size and high performance. To design a persuasive evaluation around these limiting factors would be expensive and require the participation of additional school districts.

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